Building Information Modeling for Integrated Low Carbon Infrastructure model through the analysis of energy efficiency and daylighting

By
CHIM SOTHEA

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (HONS)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved by

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Universiti Teknologi PETRONAS

TRONOH, PERAK

December 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

CHIM SOTHEA

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ABSTRACT

This report aim to give the detail analysis of the building energy efficiency and daylighting for integrated low carbon infrastructure. The analysis is supposed to be done using Autodesk Revit 2014; however, the process of equipment's tendering and contract takes too long beyond the author's time frame of submission. Hence, the author instead do the analysis through Virtual Environment 2013 from Integrated Environmental Solutions.

This Report is divided into five sections. In section 1, we will talk about the overview of the building information modelling and the need of low carbon infrastructure in today's industry. Section 2 highlights the preview of this project following by the background of study. Section 3 explores the specific research methodology following by project's key milestone, Gantt chart and list of tool requirement. Section 4 presents the detail of project's technical analysis, result and discussion. The last section brings the conclusion and recommendation of the project.

This report will be an important archive for the author since this might be the author's first official report for the university. It is quite an opportunity to be given lots of chances involving with research industry.

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my supervisor Assoc. Prof. Dr. Mohd Faris Khamidi and Assoc. Prof. Dr. Nasir Shafiq for the continuous help and support, for his patience, motivation, enthusiasm, and immense knowledge. Their guidance helped me in all the time of my work and writing of this paper.

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Last but not the least, I would like to thank my family: my parents Chheav Hun and Chim Sothy, for giving birth to me at the first place and supporting me spiritually throughout my life.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The demand for low carbon infrastructure facilities with minimal environmental impact is increasing. Rising energy costs and growing environmental concerns are the catalysts for such high demand. The environmental and human health benefits of sustainable (also called green) buildings have been widely recognized. A slight increase in upfront costs of about 2% to support sustainable design, on average, results in life cycle savings of approximately 20% of total construction costs; which is more than ten times the initial investment. Hence low carbon infrastructures are economically viable too. Worldwide, individuals and organizations have responded to the increased demand for green buildings. Many countries and international organizations have initiated rating systems for sustainable construction. Currently, a number of different rating systems are used to rate the environmental performance of buildings. These include but are not limited to: Australia's Green Star; Canada's LEED Canada; Germany's DGNB Certification System; India's IGBC Rating System and LEED India; Japan's Comprehensive Assessment System for Building Environmental Efficiency; New Zealand's Green Star NZ; South Africa's Green Star SA, United Kingdom's BREEAM, the United State's LEED, and Malaysia’s Green Building Index. Most of these rating systems' primary criteria are similar in that they evaluate a building's energy consumption, water efficiency, material use and indoor environmental quality. Under certain credit categories, multiple points may be earned for higher environmental performance levels. In addition to credits, each section includes prerequisites which must be earned (compulsory) even though they do not count towards a building's point total.

In the construction industry, Building Information Modeling (BIM) is a useful tool that can create accurate scheduling timetables and calculate, and ultimately reduce, the costs of a building project. Using BIM, a ‘virtual’ building can be constructed to analyze the feasibility of a project, which helps to design structures that reduce waste, optimize energy, and lower carbon footprint. Information from multiple disciplines, companies and project phases can be combined and features of BIM include highly detailed and realistic images of the building structure; a 3D model integrated with cost, energy and structural analysis; and 4D scheduling

1.2 Problem statement and scope of study

Low carbon infrastructure is necessary because the need for development is as great as ever, but the model of the past cannot be used as a pattern for the future. Millions of people worldwide live below the poverty line, have no access to health care, and have inadequate shelter. With the rapid increase of the global population, the disparity between rich and poor is becoming greater.

When comes to the topic of BIM for site condition, there are always two questions that need to be concerned. One is how to create a 3D site information model separately from the building model by using real life project data, this process does not only mean to create simple topography from existing site project files, but also to provide a site model that will carry all necessary site information including terrains, orientations, elevations and the underground situation such as ground conditions, drainage and piping system. In the world of BIM, 3D parametric and object oriented software also allows for the same operational characteristics in the model, that is, one small change would make a complete difference, because all 21 associated parts would be instantly and dynamically updated (Turner, 2007). So a major concern is to find out a way to effectively link the independent building model and site model together, and to what extend should the building model include parts of the site model.

The project essential is to design and simulate an infrastructure in the form of building for lower carbon usage. Flowchart below explain the project planning for the whole process.

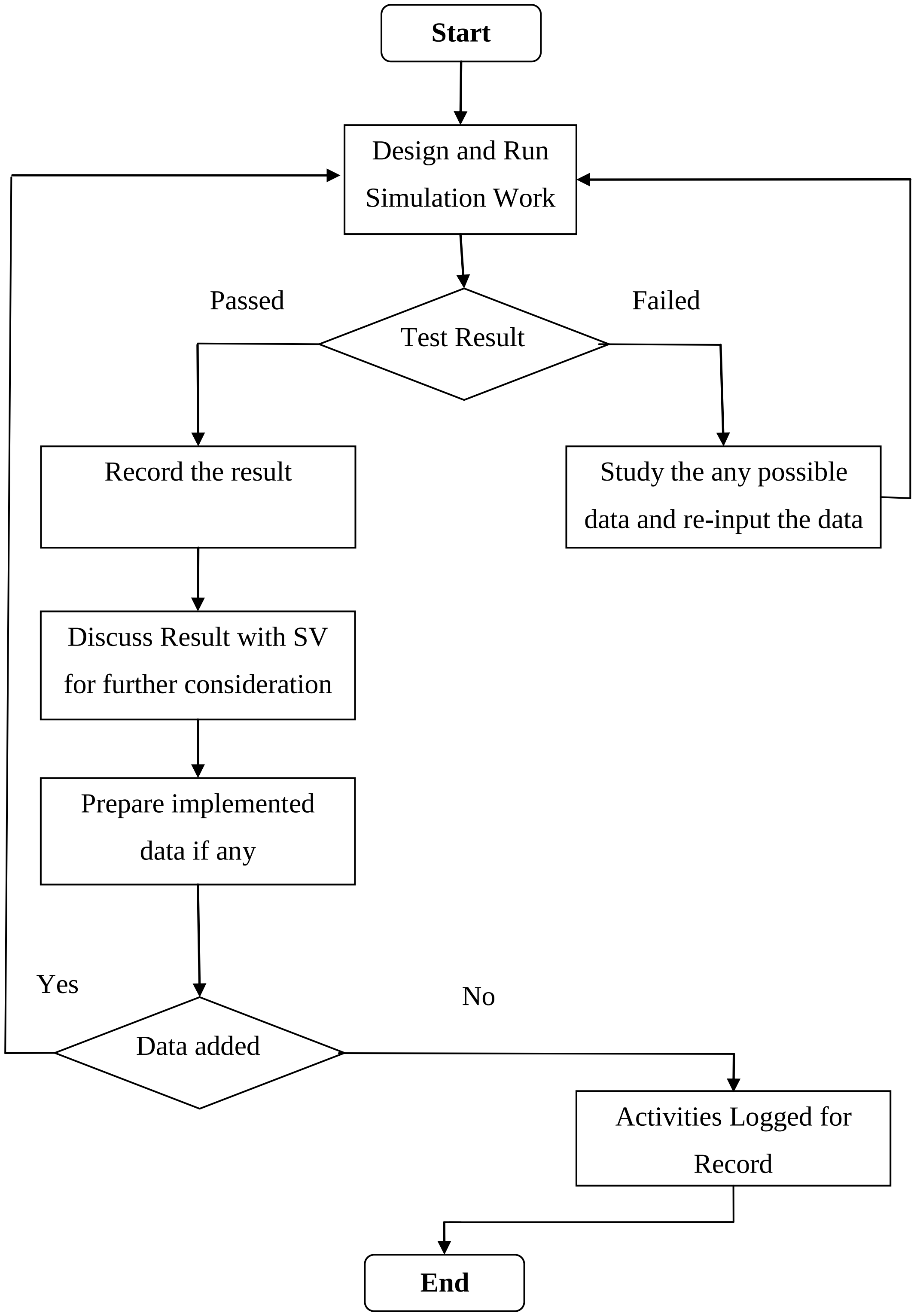

Figure 1: Project's Flow chat

1.3 Aims and Objectives

The objectives of this project are:

- To run a simulation work of the building 3D model using IESVE.
- To analyse Energy Efficiency and Daylighting value of the model.
- To discuss the advantages and limitations of applying BIM for low carbon infrastructure in site design and construction.

1.4 Feasibility of Project

In terms of feasibility of realizing the objectives of this project, the author of this document has taken an internship training in a green building design company, specifically been trained to run simulation using Integrated Environmental Solution 2012 (IES-V2012). The author intends to take upon the study of Autodesk Revit 2014 during his final semester whereby he will also complete this project. As such, there are no problems regarding technical feasibility.

Due to time and financial constraint, the focus of this project is solely on the design and simulation of integrated low carbon structure. The initial plan for this project is to design and perform a simulation tests on a low carbon infrastructure which enables a similar level of service from existing networks but with greatly reduced carbon emissions over traditional approaches. As such, we can effectively demonstrate how the design and simulation of a low carbon infrastructure through the analysis of building energy efficiency and daylighting. Furthermore, the cost of the software and other electronic devices needed will be covered by research grant. We will also not take up time to understand the intricate nature of installing and understanding the software for the simulation work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the definition of “Building Information Modelling” and “Low carbon infrastructure” are given as below.

2.2 Building Information Modelling (BIM)

The AEC industry accepted word “Building information modeling” and its three letter acronym “BIM” is regarded as the new approach to computer aided design (CAD). There has been some confusion in the industry what to call this new approach, and words from “Virtual Building Model” to “Single Building Model” have been thrown about. BIM is a version coined by the biggest CAD software vendor Autodesk and it seems the rest of the vendors just nodded in favor, due to Autodesk’s superior marketing power. How to take advantage of this new approach differs between these software vendors and their own definition on the matter. To some it comes mainly down to the software tool itself and its capabilities. To others it is the new methodology that BIM brings to the industry, of how to approach the design, analysis and documentation of buildings, which matters most. Generally it is widely accepted that, as a tool, BIM will potentially lift the design process to another level and hopefully match the effectiveness of the automotive and aeronautic industries. But the main function of BIM is managing information throughout the whole lifecycle process of a building, from the concept stages through construction documentation, completion and administration. This information is basically every input of data that is necessary when designing a building, e.g. the total of doors and windows, the cost of construction materials, the energy consumption of the building and so forth.

The digital model part of the BIM process combines graphical project data, such as 2-D and 3-D drawings, with the non-graphical information, like specifications and schedules. From this virtual model and its database it is possible to extract the appropriate visual or documental data whenever needed. More importantly the database is object-oriented which means it consists of intelligent objects not only collections of lines like the 2-D CAD offers. In BIM these objects can contain information on its measurements, cost, producer and even more. The BIM modeling approach is also coordinated in a way that the database is automatically updated if an object is changed or modified. If we take a window object for an example, and its size or position is changed in the model, the database rectifies all affected information to that particular window. That can be everything from the plans, elevations and sections to schedules and even project cost if the window is erased. This particular function of BIM is often presented as parametric modeling. BIM offers project teams a much better overall solution than the traditional methods they have been using until now. The up-to-date robust model of the project is not the only advantage as it also minimizes errors during input of information. Everything is centralized and interconnected so the various team members do not need to re-input data. If any particular information needs to be updated, the entire model instantly updates. That takes care of the problem, which occurs so often with traditional 2-D CAD workflow, what versions are up to date or out of date. These advantages improve coordination and the celerity of workflow considerably. BIM increases team efficiency, productivity and trust. This trust gives team members more confidence that the documents involved in the project are correct. That leads to an overall better working environment during the project and possibly makes the work more of a pleasure then nuisance.

2.3 Low carbon infrastructure equipment

It is clear that, alongside energy efficiency measures, certain types of installations of low carbon equipment should have a part to play in achieving the Scottish Government's targets for reducing carbon dioxide emissions. However having considered evidence from research and from recent experience, we do not consider that the industry is yet sufficiently well developed to justify mandatory requirements in building regulations for low carbon equipment or to require all buildings to become generators of electricity. We also have concerns about the issues identified below. The cost of energy generation when viewed at the level of individual buildings could be such that it will tend to discourage development. This is particularly applicable to the provision of affordable housing, where the investment could be significant and the returns are of relatively limited benefit. Some low carbon equipment in housing can make services systems substantially more complex, more difficult for occupants to understand and more expensive to maintain. Alternatively, investment in reducing the carbon dioxide intensity of the UK energy supply alongside energy efficiency measures in buildings would produce better value, more substantial and reliable production than numerous small-scale, building-integrated technologies. Below lists a few criteria considered for low carbon footprint infrastructure simulation:

a. Optimize Site Selection

The location

- Redevelop a Brownfield
- Use an existing structure and renovate the building
- Easy accessibility of roads, parking and public transportation

Orientation/Shape of the Building

- Orient your building in a specific way to optimize your heating or cooling needs

- Allow in as much daylight as possible by specifically designing your building with windows that maximize the amount of natural light throughout the interior spaces. This will help you control electric lighting costs.

Landscaping

- Co-create with the environment and natural surroundings. Through the use of indigenous greenery, heat and storm water will be efficiently absorbed reducing cooling costs and pollution runoff.

b. Optimize Energy Use

Lighting

- Control the amount of natural light let into the interior of the space by incorporating design elements such as:
    - Clerestories-glass partitions above interior walls to let more natural light in
    - Photo Voltaic Sun Shades
    - Color Rendering Lamps
    - Dimmable Electronic Ballasts

Electricity Usage

- Use energy efficient office equipment that have an energy star label
- Take advantage of the energy efficient light bulbs and fixtures as they will significantly reduce your electricity bill and last much longer than traditional bulbs.
- Install sensors to control lighting and HVAC in areas that are being used less frequently than others.
- Utilize renewable energy by implementing solar panels into your design

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is intended to deeply elaborate the research processes, design and development activities in this project. In a nutshell, the research can be broken down into four layers of activities. This chapter will also summarize the tools and equipment that will be required in realizing the objectives of this project. These layers are interdependent and timelined.

The first layer will take form in a requirement gathering like activity. In this pre-development study stage, we will obtain all necessary requirements for the simulation work which will gear towards achieving the objectives of this project. The second layer will be the designing of the building using selected software and all the necessary secondary modules which is required for this project. The third will be the development of the simulation work, which involves multiple testing of data simulations to ensure that it is working as intended and finally, the calibration of the simulation result, and adding of functionalities to it in order to finalize the project result.

3.2 Research Methodology

To create a site-linked BIM model, one needs to first seek for current technology support. As previously stated in this report, there are currently three major software vendors who provide technology resources for this purpose: Autodesk Inc., Bentley System and Graphisoft SE. This chapter reviews the approaches that can be followed to create the site-linked BIM model by using different software provided by these vendors. This is done through the following three steps:

- Find out the corresponding BIM software for both the site and building modeling.

- Discuss the software interoperability with other BIM tools.

- Provide all the feasible methods of creating a site-linked building model.

Three vendors provide some corresponding BIM solutions for Building and Site design. Autodesk, Inc. has Revit for building modeling and Civil 3D for site modeling. As described by Autodesk, Revit Architecture building design software was built for BIM. And it could help the architects and designers to develop high quality designs, to better capture and analyze concepts and versions through design, and to produce a better coordinated documentation for construction (Autodesk, 2010). On the other hand, Civil 3D is a BIM solution for Civil Engineering design and documentation. The software is suitable for transportation, land development and water resources engineering project, it is also the most commonly used software for site modeling in the current industry.

Bentley system provides Bentley Architecture, which serves the building design like Revit Architecture. For site modeling, InRoads Site Suit runs on Microstation and AutoCAD, provide the powerful functionalities of site, survey and drainage, as well as the cohesive solution for land development and site modeling (Bentley 2011); PowevCivil offers civil engineers and designers a flexible 2D/3D tool for land development and site model, it is suitable for commercial building sites, campuses, as well as the drainage utility projects (Bentley, 2011).

Graphisoft does not have as many products as the other two software vendors do, its core product, ArchiCAD is mainly developed for Architectural and structural design;

however, this BIM tool does have some features that would enable some simple site design.

For interoperability, since all the BIM tools for building and site model support the CAD DGN and DWG format, theoretically, the model could be imported and exported smoothly among different software. However, to get a better performance of the model, some integration software could be used such as Navisworks and Bentley Navigator. This would integrate the pieces of model made by different software together; provide better control and coordination of the overall project outcome.

After been through the pros and cons from the above table, author and his supervisor has decided to choose Autodesk Revit from Autodesk Inc. for the design and simulation work of this project. However, due to the time constraint as the process of delivering the software (Autodesk Revit), the author instead create the 3D model and run the analysis through IESVE.

3.2.1 IESVE

Virtual Environment (VE) Modelling is a cutting-edge suite of building performance simulation tools. Used by leading sustainable design experts across the globe, it creates understanding of the performance impacts of different low-energy design strategies. IES VE is integrated software that uses different modules for different type of assessment. Each module in the software is described in below sections. IESVE allows us to design and operate comfortable buildings that consume significantly less energy and incorporate low-carbon and renewable technologies.

Whether working on a new build or renovation project, our software allows designers to test different design options, identify best passive solutions, compare low-carbon technologies, and draw conclusions on energy use, CO_2 emissions, occupant comfort, light levels, airflow, Part L, BREEAM, LEED, EPC ratings, and much more.

3.3 Key Milestone

There are few key milestones in this project. The first one is the identification of all the components that are required. The second is the design and simulation phase of the building. The next one is the development of the simulation work for the first delivery and the finally, after the iterative process is completed, the result will be ready to be delivered.

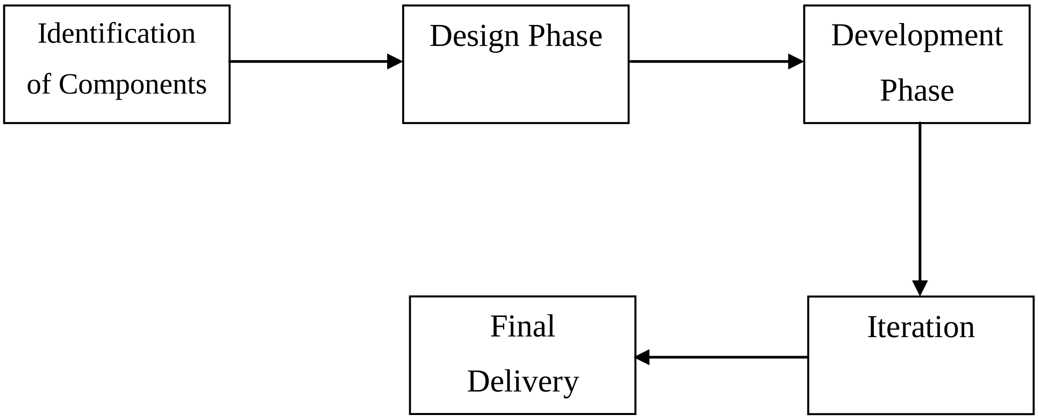

Figure 2: Key Milestone

3.4 Gantt Chart

Task	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Literature Review							
Develop project proposal							
Pre-Development Study							
Identification of Components							
Design of infrastructure for simulation work							
Development of simulation work							
First Delivery of simulation work							
Testing and Calibration							
Iteration and Re-modification							
Final Delivery							

Table 1: Project Gantt chart

3.5 Tools Required

In this project, we will utilize this hardware and software:

No	Name	Roles
1	High performance PC	Data simulation work
2	IESVE 2013	Data simulation work

Table 2: Tool required for project

CHAPTER 4

RESULT AND DISCUSSION

4.1 Modelling Overview

4.1.1 Computational Modelling Software

The building has been constructed using the world class “Virtual Environment” (VE) produced by Integrated Environmental Solutions Ltd., allowing solar penetration calculations using Sun Cast, ApacheSim module, and Daylight Factor (DF) calculations using Radiance.

Radiance is internationally recognised as one of the leading lighting simulation tools available. The Lighting Systems Research group at the Lawrence Berkeley Laboratory in California, USA, developed radiance as a research tool for predicting the distribution of visible radiation in illuminated spaces.

It takes as input a three-dimensional geometric model of the physical environment, and produces a map of spectral radiance values in a “photo-realistic” colour image. It conducts a dynamic simulation for the whole year and can be used to calculate lighting levels (LUX), Daylight Factors or Glare for daylight and/or artificial lighting.

Measurements was taken at fixed floor level and referred to as the working plane. This is in keeping with the Green Building Index compliance requirements.

Using Radiance, a DF contour map has been calculated for the intended floors. A threshold map describing those areas with a minimum DF of 1% is used to calculate the area of office space which receives adequate daylight.

Virtual Environment (VE) Modelling is a cutting-edge suite of building performance simulation tools. Used by leading sustainable design experts across the globe, it creates understanding of the performance impacts of different low-energy design strategies. IES VE is integrated software that uses different modules for different type of assessment. Each module in the software is described in below sections.

4.1.2 Model IT

ModelIT is the single central 3D data model at the heart of the system that provides geometry and data shared by all tools. It collates & shares information on geometry, materials, occupancy, climate and equipment within all modules or tools. ModelIT enables the user to create a 3D analysis model from scratch or alternatively, import CAD data into the system in 3D or 2D. This tool also support imported file from SketchUp, Revit, Affinity, gbXML, DXF. It stores data in one central place & creates dynamic visualisations.

4.1.3 Suncast

SunCast analyzes how solar gains impact the building. It allows visualizing the solar radiation on the façade and interior surfaces, and assessing the effectiveness of shading strategies. These impacts are also quantified in terms of heat gains and energy consumption to help optimize shading design once integrated with ApacheSim. This section will show how to setup the model to create the visualizations and how to perform the simulation for the thermal and energy analysis.

4.1.4 ApacheSim

ApacheSim is the thermal simulation engine in the Virtual Environment (VE). It models the dynamic interactions between the building, the external climate, the internal loads and processes, and the building mechanical systems. It is capable of integrating data from the other VE modules to analyze solar radiation, daylight harvesting, natural airflows, and detailed HVAC system performance. This section will show the basics of room thermal properties, how to perform simulations and review results to assess the benefit of adding the solar shading. Additionally, a high performance glass option will be simulated as another design scenario.

4.1.5 Radiance

Radiance module is used to ensure good natural daylight and visual comfort, reduce lighting gains, and test how the building's lighting designs will look and perform. It allows detailed 3D visualisation of daylight and electric light levels. The simulation in radiance will help to design building in order to maximise daylight, minimise glare and incorporate electric lighting designs. Using the module, sensors can be placed and accurate daylight levels for dimming controls can be recorded.Dimming profiles to lighting gains in can be applied in ApacheSim to quantify energy reductions.

4.1.6 Virtual Environment Modelling

In OTTV and RTTV assessment, it is required to virtually build the model as one even though only occupied or conditioned area are considered in the assessment. Figure 3 and 4 shown below are the conceptual view of the building in IESVE model.

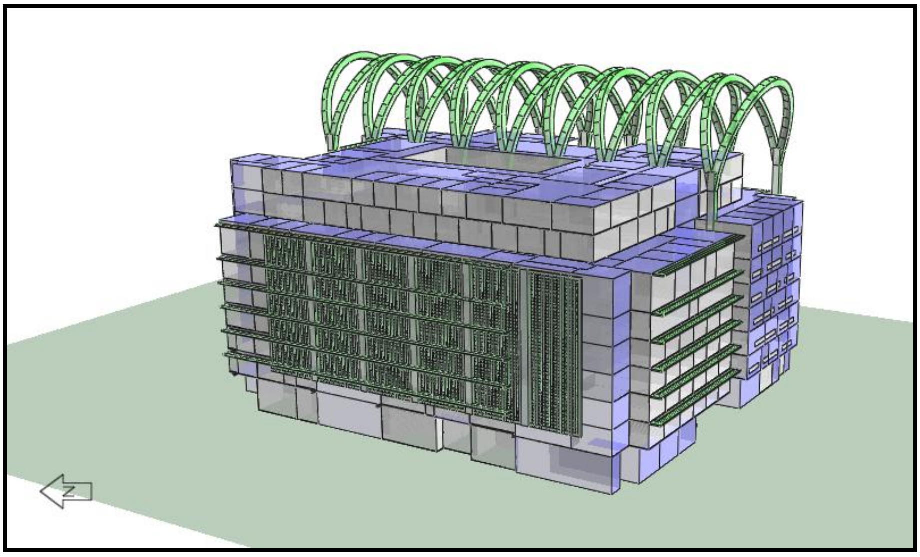

Figure 3: Model from West View

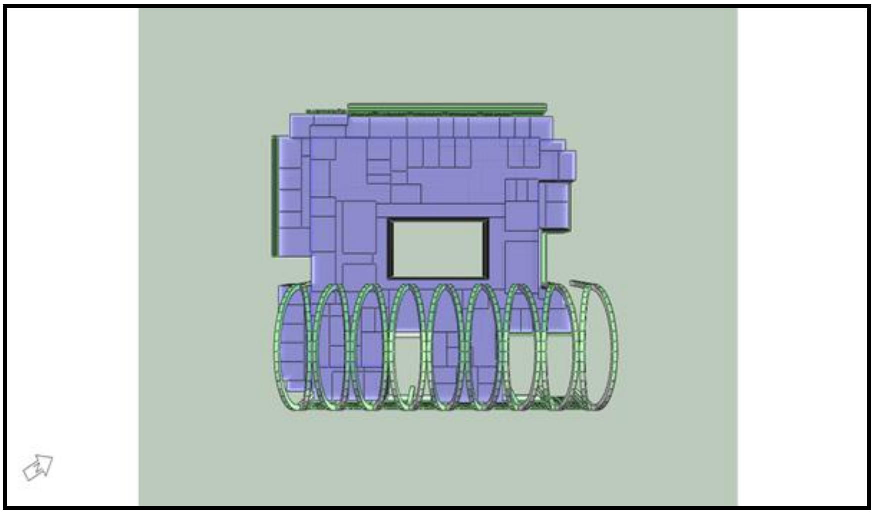

Figure 4: Model's Top View

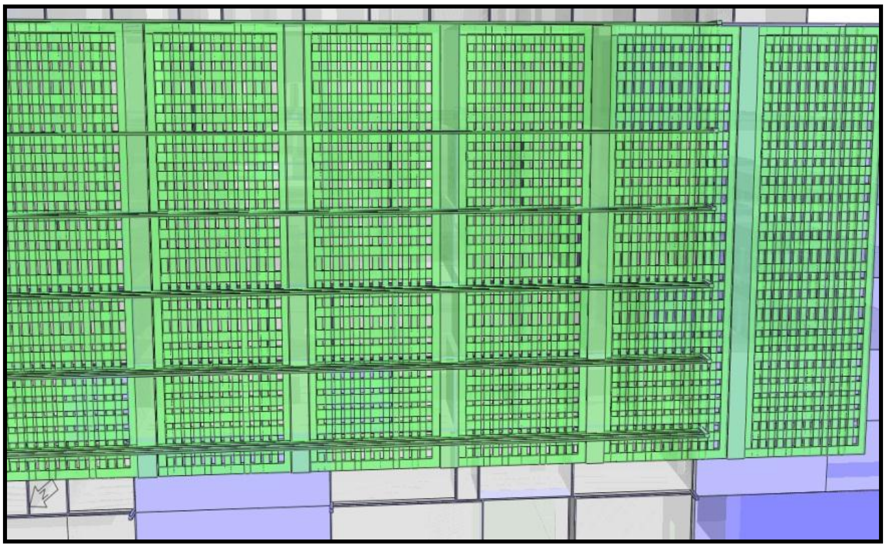

Figure 5: Close View of Vertical Shading Devices

Building parameters used for the modelling assessment is as follows:

Total AC Floor Area	22,473.46	m^2
No of Floors (including Ground)	10	floors
Floor to Floor Height	4.00	m
Proposed Plot Ratio	4.86	
Building Orientation	West	
Floor Area per floor (Roof Area)	2,247	m^2
Building Length (Local North)	78.00	m
Building Width	64.00	m
Building Height	53.35	m

Table 3: Building parameters

4.2 Energy Efficiency Analysis

4.2.1 OTTV & RTTV Derivation

Figure below shows the process flow involved in the simulation to derive the OTTV and RTTV for the development.

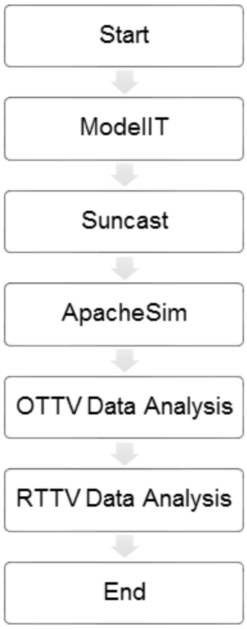

Figure 6: Flow chart for OTTV & RTTV simulation

Table below show the areas included and excluded for OTTV and RTTV calculation.

Included	Excluded
Office Room	Utility Room
Pantry	Stairs Area
Lobbies Area	Corridor and Driveways
-	Toilet

Table 4: Projection Area of OTTV

4.2.1.1 Weather Data

IES-VE calculates OTTV of the building envelope using real time calculation incorporating local weather data and construction materials of the building. The simulation used Kuala Lumpur local weather data taken from ASHRAE design weather database.

The design weather data is used to determine peak loads, and the simulation weather data is used for the full year simulation.

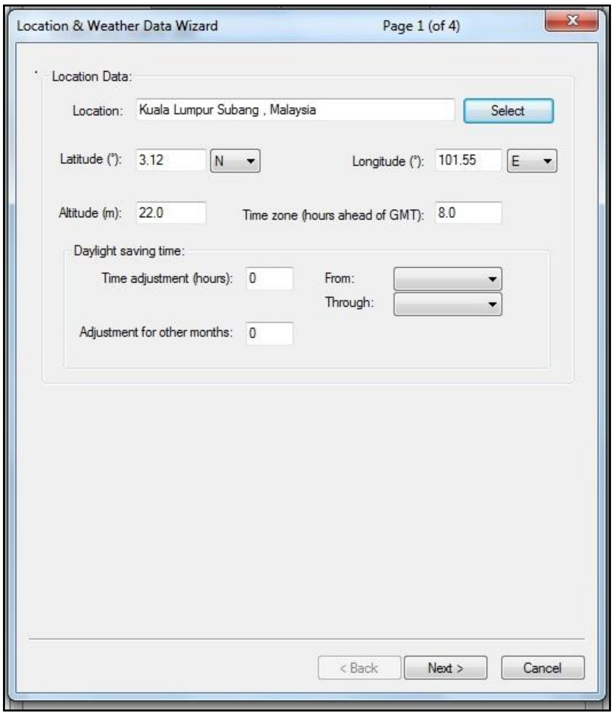

Figure 7: Setting up Location and weather data calculation in IES

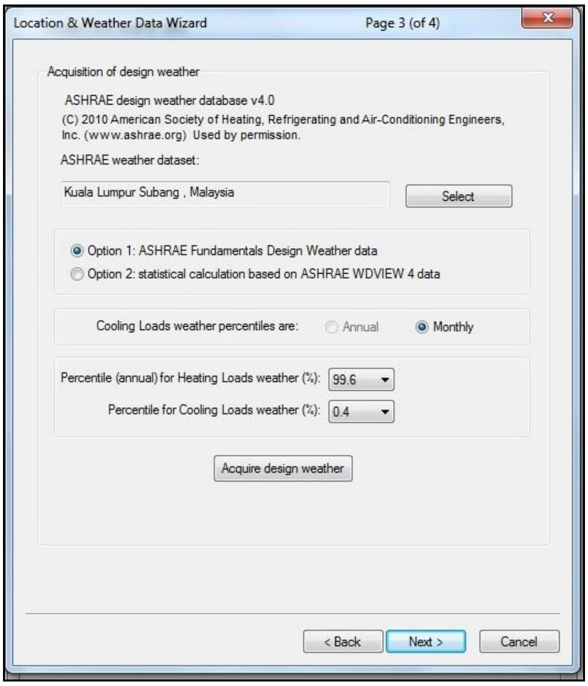

Figure 8: Selecting Option for Designed Weather data

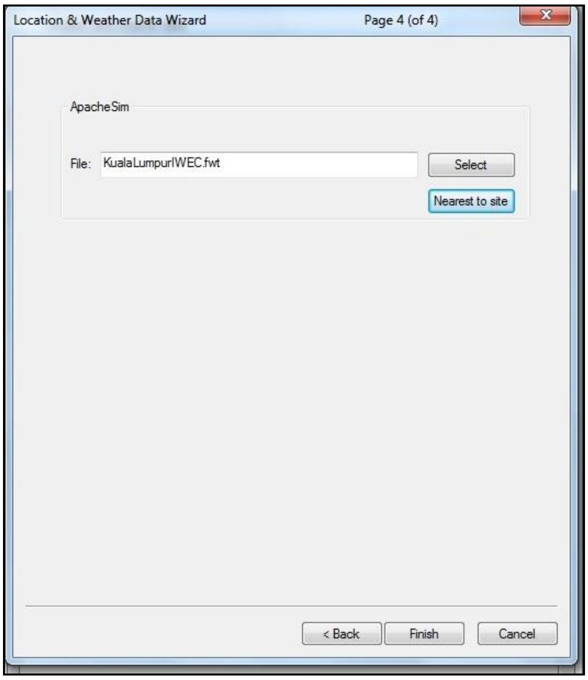

Figure 9: Choosing file of destination's location

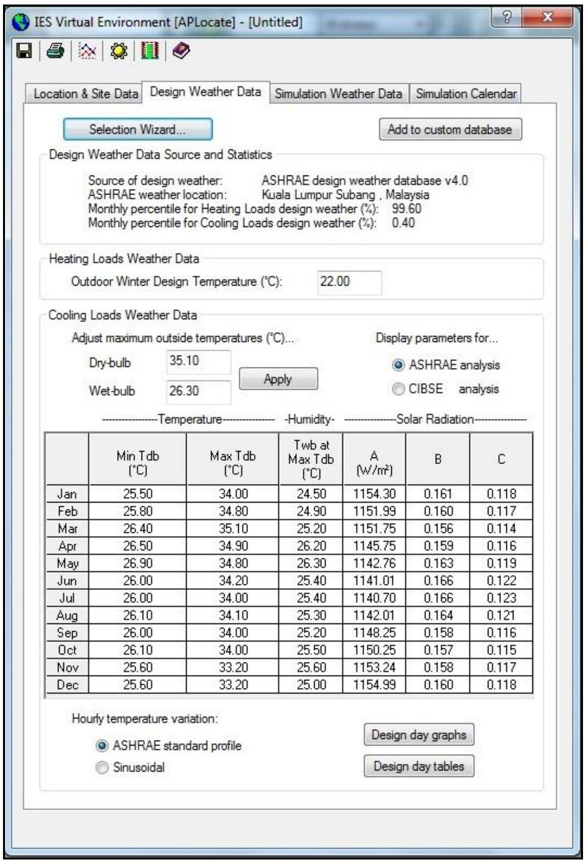

Figure 10: Checking the weather file information

4.2.1.2 Overall Thermal Transfer Value (OTTV)

Overall thermal transfer value defined as quantity of heat transferred per unit of temperature difference into a building through its walls or roof, due to solar heat gain and indoor-outdoor temperature difference.

The OTTV requirement is aimed at achieving the design of adequately insulated building envelope so as to cut down external heat gain and hence reduce the cooling load of the air-conditioning system. The OTTV concept takes into consideration the three basic elements of heat gain through the external envelope of a building, as follows:

- Heat conduction through opaque walls
- Heat conduction through glass windows
- Solar radiation through glass windows

The OTTV of building envelope is given by the formula:

$$OTTV = \frac{Ao_1.\mathrm{OTTV}_1 + \mathrm{Ao}_2.\mathrm{OTTV}_2 + \cdots + \mathrm{Ao}_n.\mathrm{OTTV}_n}{\mathrm{Ao}_1 + \mathrm{Ao}_2 + \cdots + \mathrm{Ao}_n}$$

Where,

A_{oi} is the gross exterior wall area for orientation *i;*

OTTV is the OTTV value for orientation i from equation

$$OTTV_i = 15 \propto (1 - WWR)U_w + 6(WWR)U_f + (194CF.WWR.SC)$$

Where,

WWR is the window-to-gross exterior wall area ratio for the orientation under consideration

α is the solar absorptivity of the opaque wall

U_w is the thermal transmittance of opaque wall ($W/m^2 K$)

U_f is the thermal transmittance of fenestration system (W/m^2K)

CF is the solar correction factor

SC is the shading coefficient of the fenestration system

The formula used in analysizing the data gained from the simulation is as follows:

$$OTTV\left(\frac{W}{m^2}\right) = Solar\ gain + conduction\ gain\ (External\ wall) + \frac{Conduction\ gain\ (external\ glazing)}{Wall\ area}$$

4.2.1.3 Roof Thermal Transfer Value (RTTV)

In the case of an air-conditioning building, the concept of Roof Thermal Transfer Value (RRTV) is applied if the roof is provided with skylight and the entire enclosure below is fully air-conditioned. RTTV takes into consideration the basic components of heat gain through the opaque roof and skylight. These are:

- Heat conduction through opaque roof
- Heat conduction through skylight
- Solar radiation through skylight

For roofs with skylight, the maximum recommended RTTV is 25 W/m^2.

The RTTV of roof is given by the following equation:

$$RTTV = \frac{(A_r.U_f + TD_{eq}) + (A_s.U_s.\Delta T) + (A_s.SC.SF)}{A_0}$$

Where,

RRTV is the roof thermal transfer value (W/m^2)

A_r is the opaque roof area (m^2)

U_r is the thermal transmittance of opaque roof area (W/m^2)

TD_{eq} is the equivalent temperature difference (K), as from table

A_s is the skylight area (m^2)

U_s is the thermal transmittance of skylight area (W/m2)

ΔT is the temperature difference between exterior and interior design conditions (5 K)

SC is the shading coefficient of skylight

SF is the solar factor (W/m^2)

A_o is the gross roof area (m^2) where Ao = $A_r + A_s$

The formula used in analysizing the data gained from the simulation is as follows:

$$RTTV\left(\frac{W}{m^2}\right) = \frac{Conduction\ gain\ (roof)}{Roof\ Area}$$

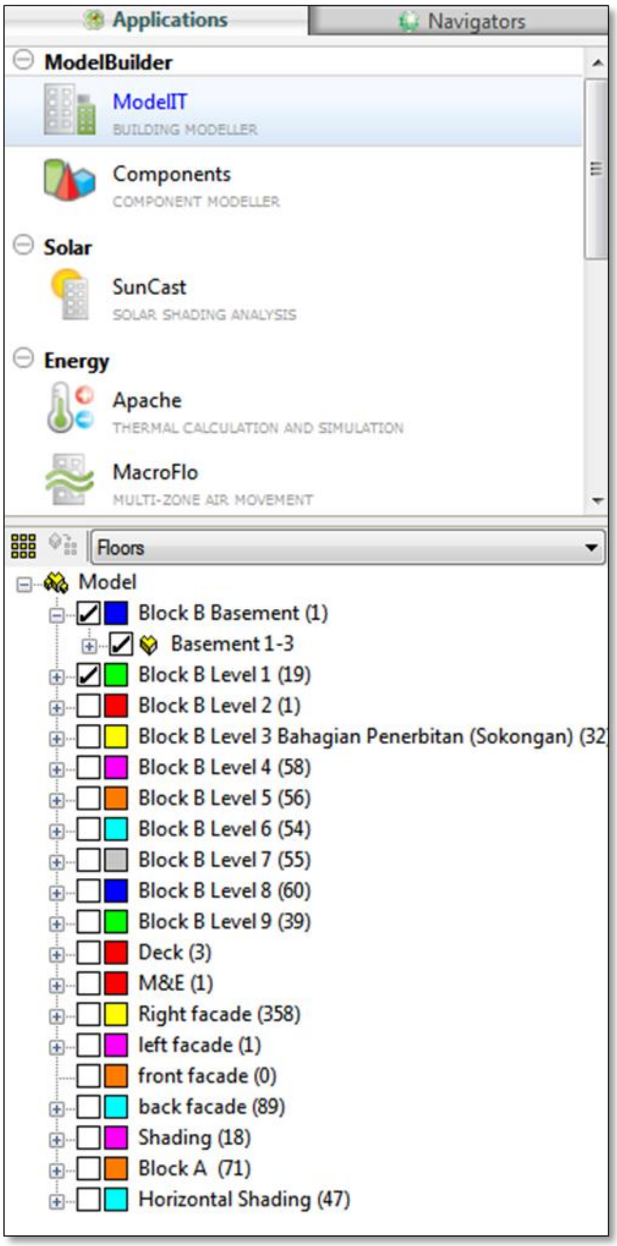

Figure 11: Building detail room and floor layer

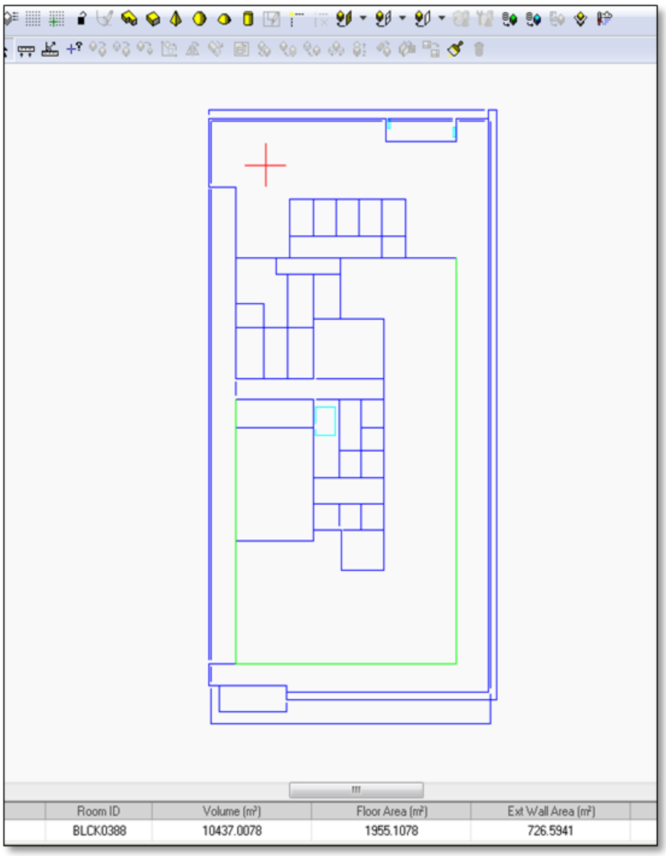

Figure 12: Selected floor level drawing

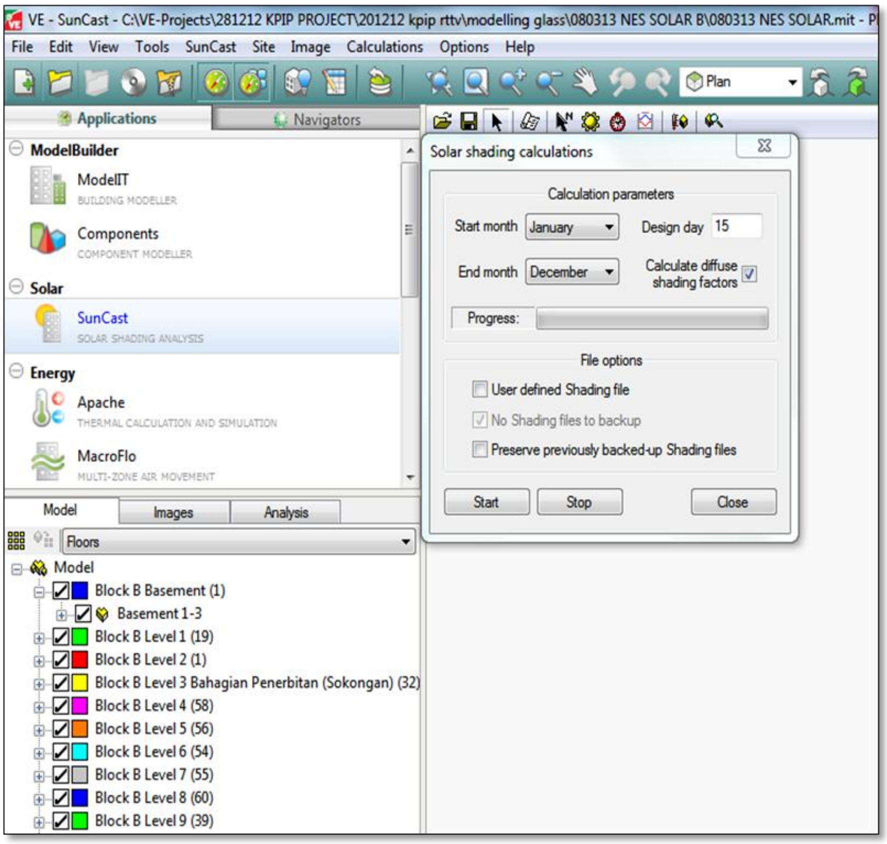

Figure 13: SunCast Analysis

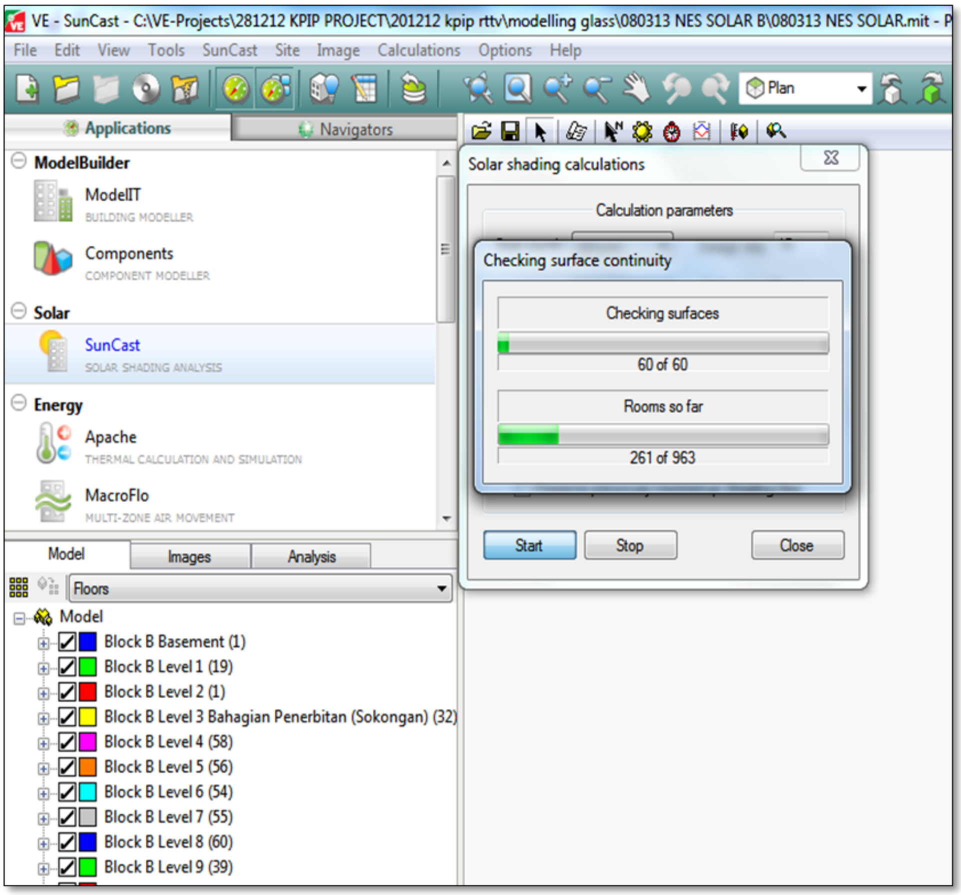

Figure 14: Progress of SunCast analysis

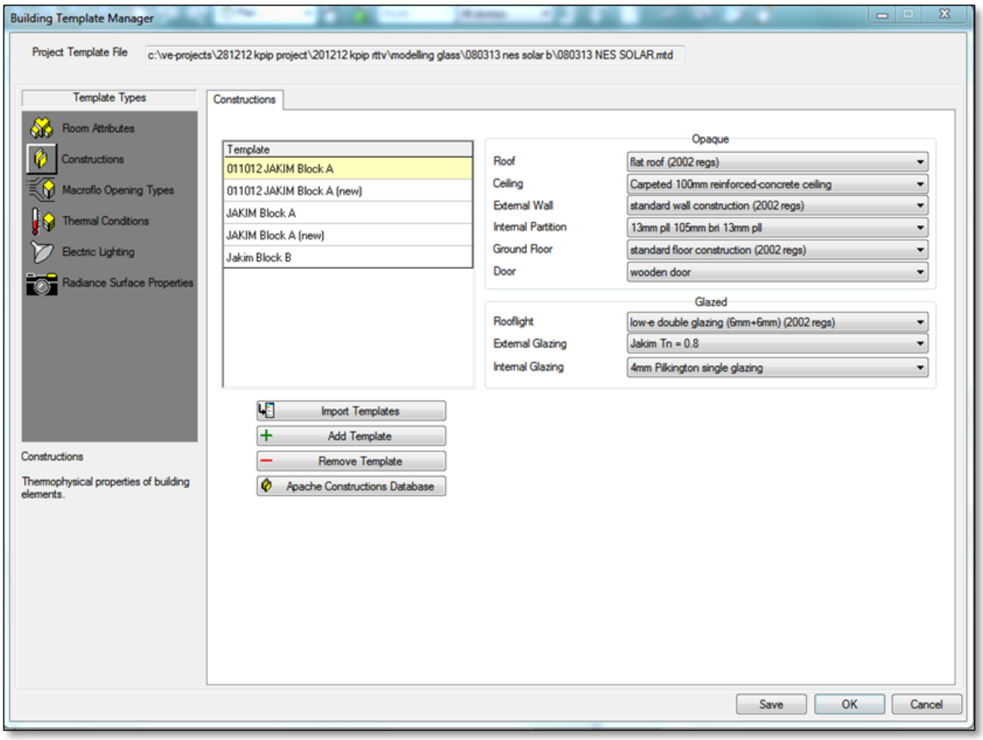

Figure 15: Building Template Manager

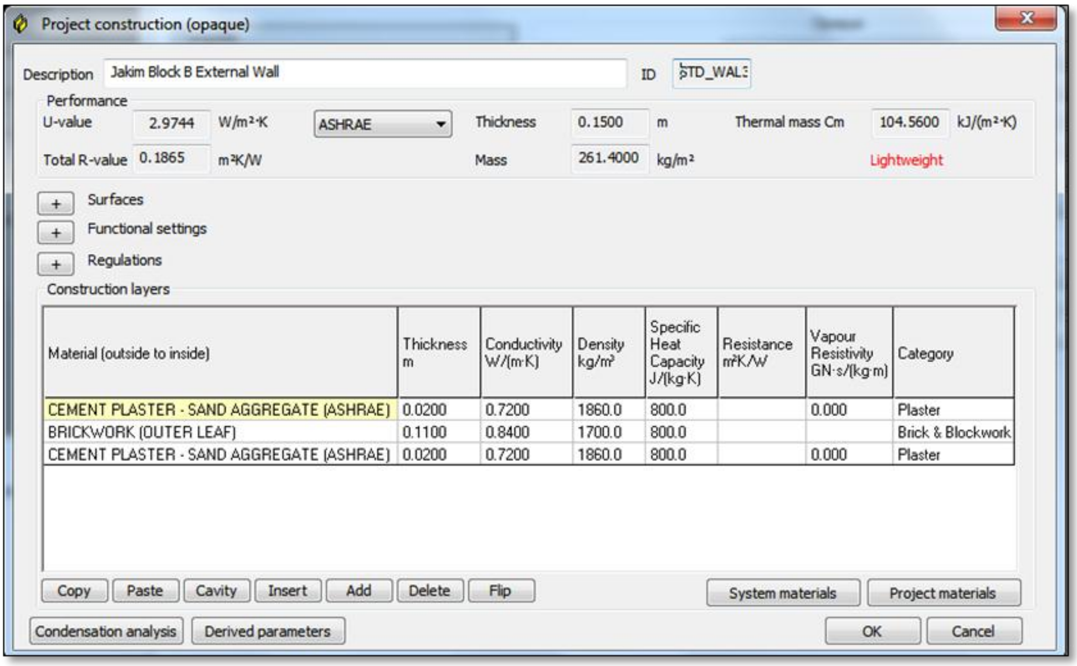

Figure 16: Inputting Building information into the Project construction

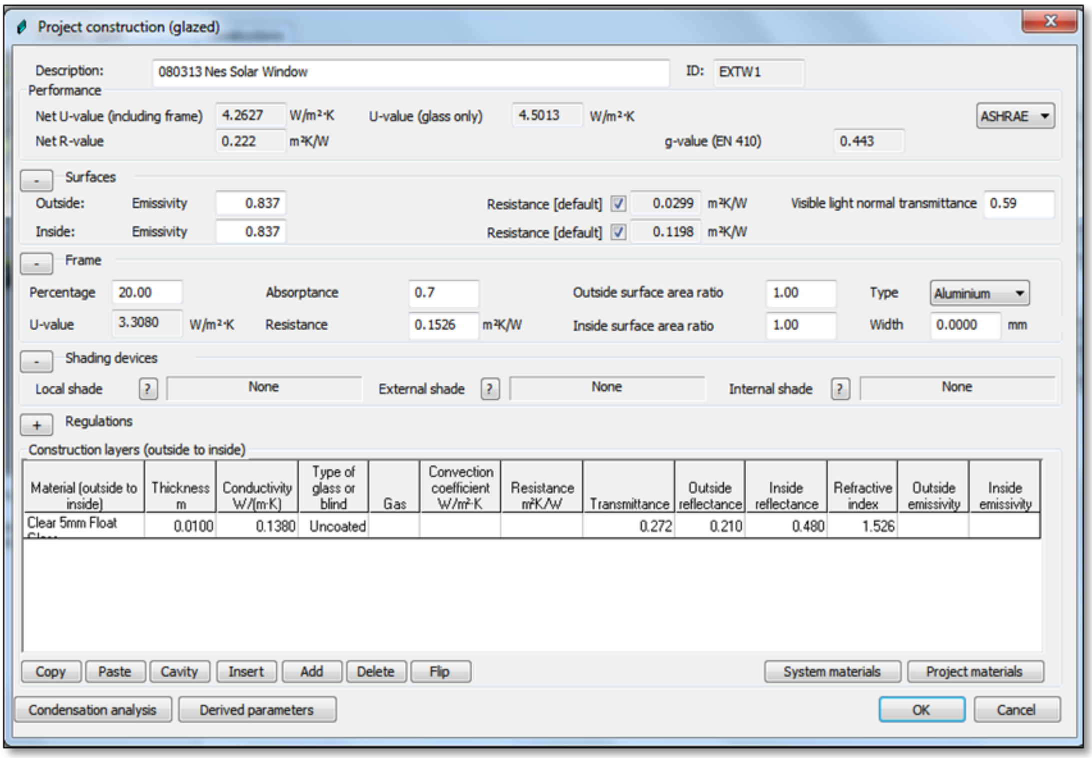

Figure 17: Inputting Building information into the Project construction

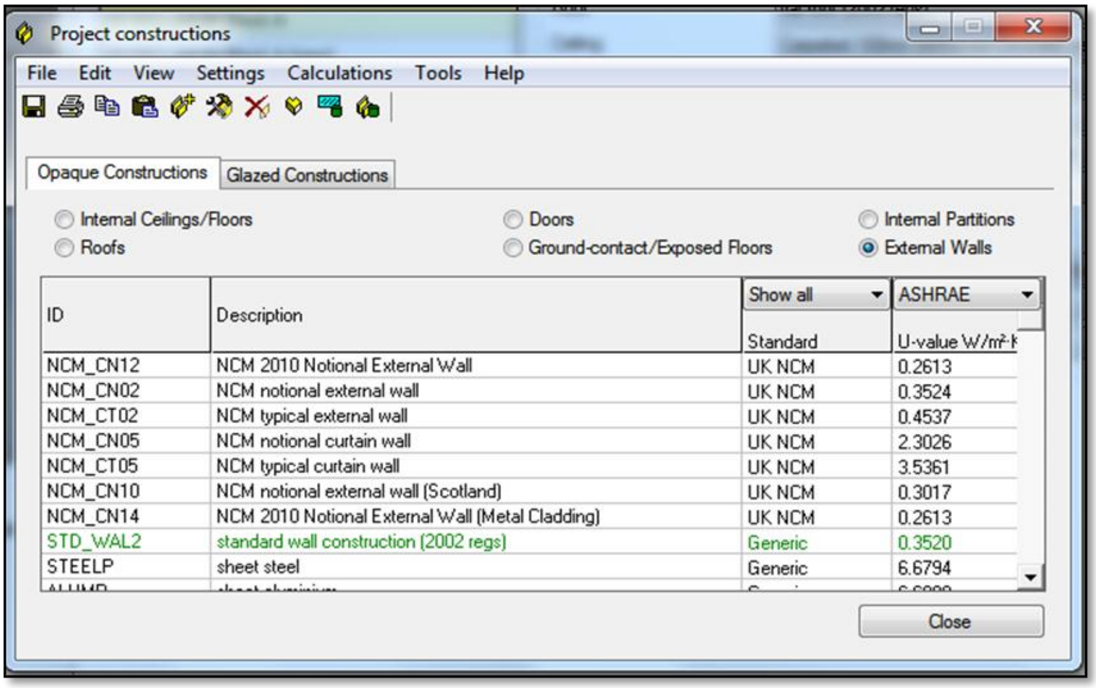

Figure 18: Inputting Glazing information into the project construction

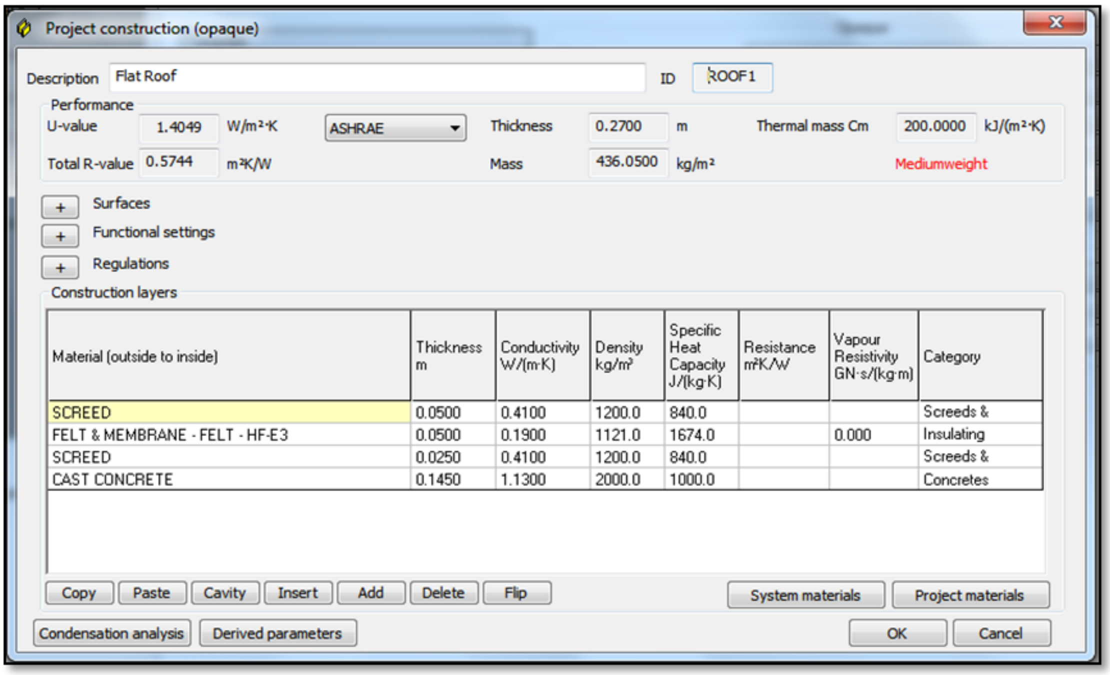

Figure 19: Adjusting Opaque data in project construction setting

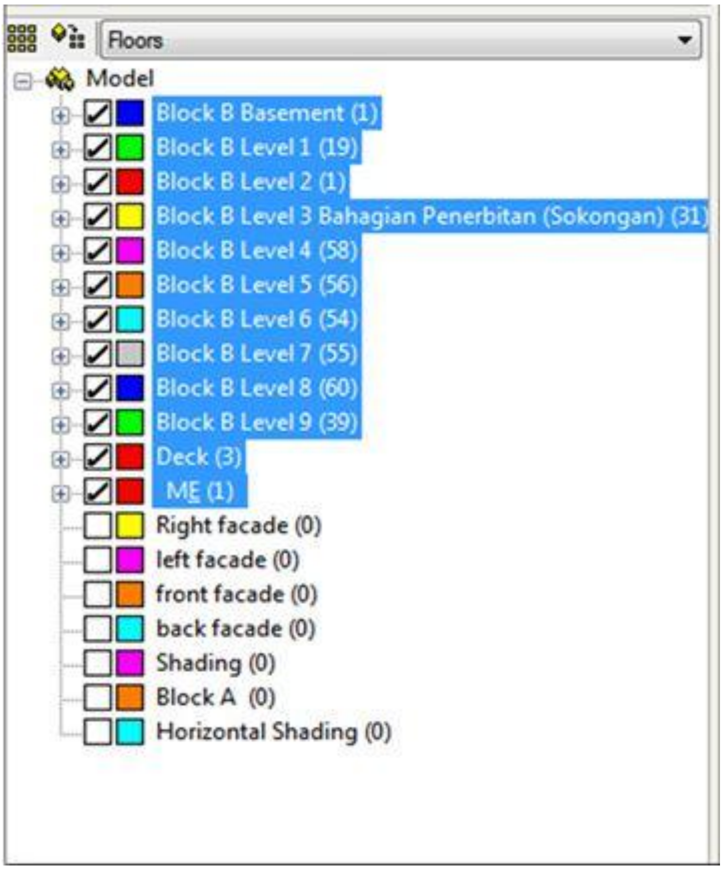

Figure 20: Selecting all occupied floor building for analysis

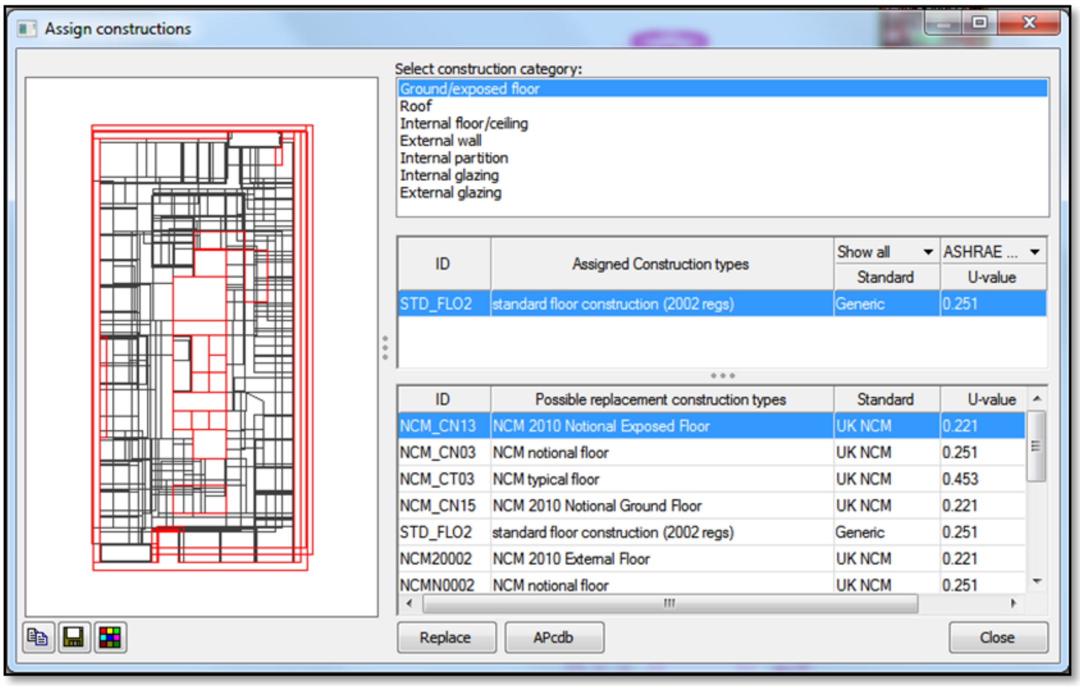

Figure 21: Checking the glazing position of the building

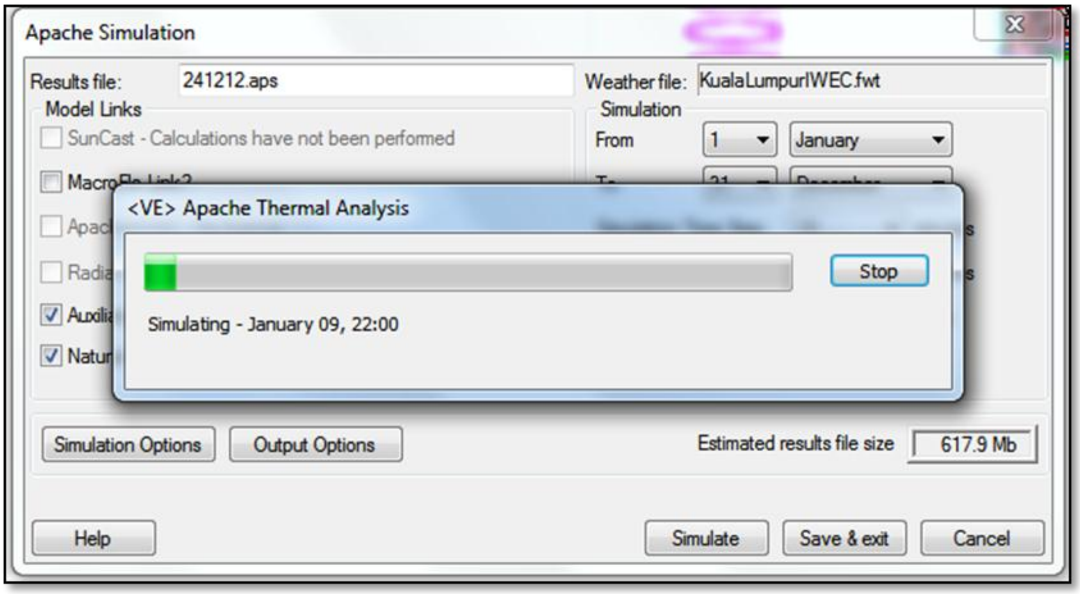

Figure 22: Apache simulation

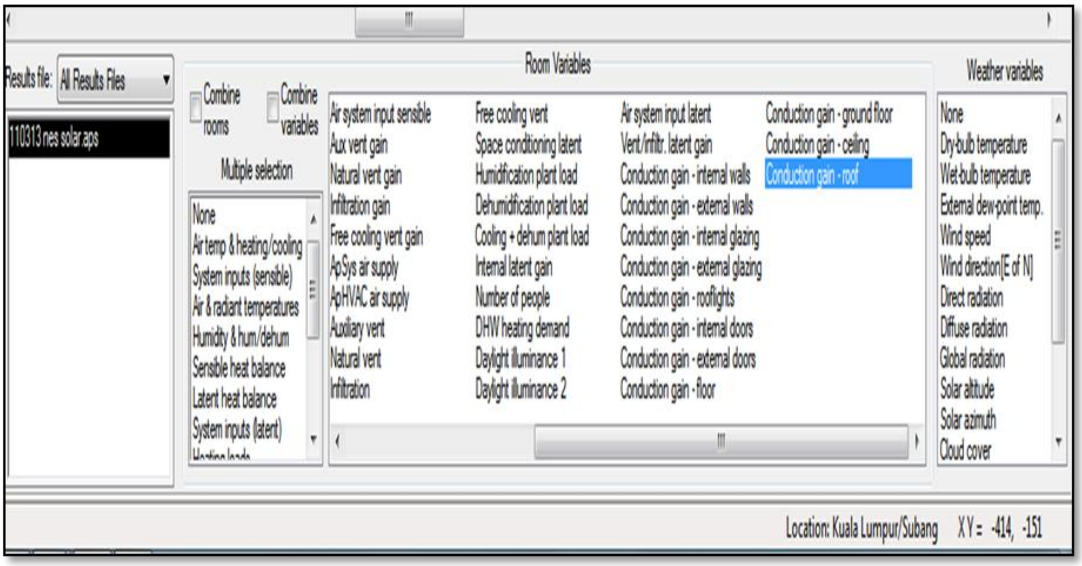

Figure 23: Selecting Room variable for the simulation

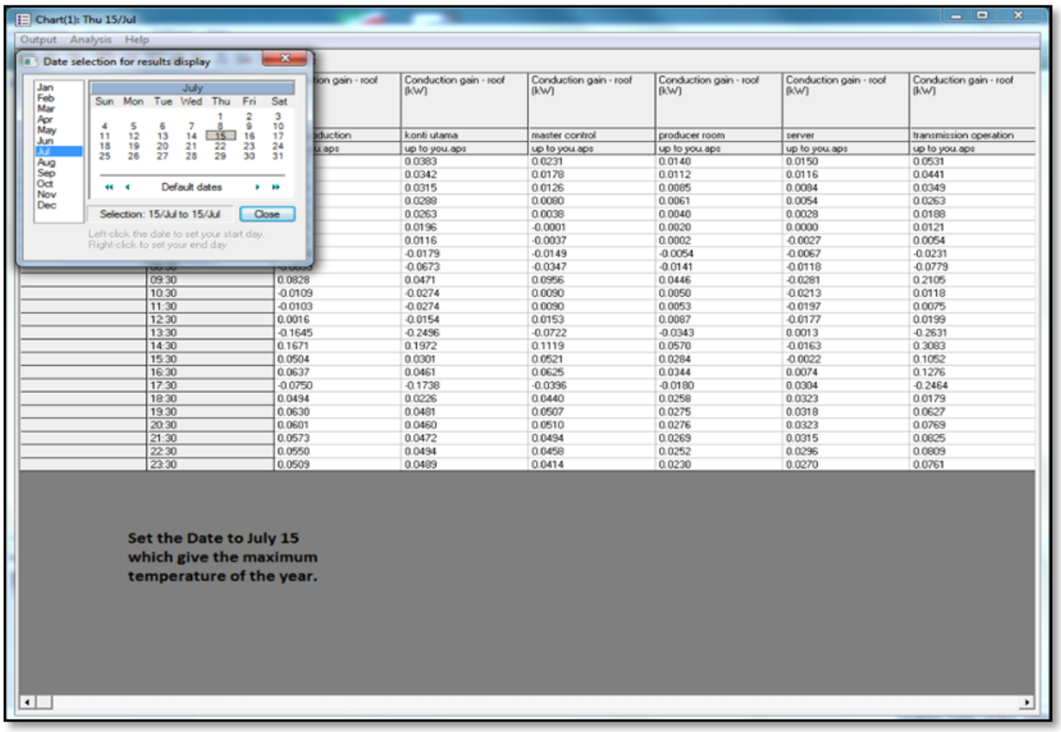

Figure 24: Selecting the hottest date of the year

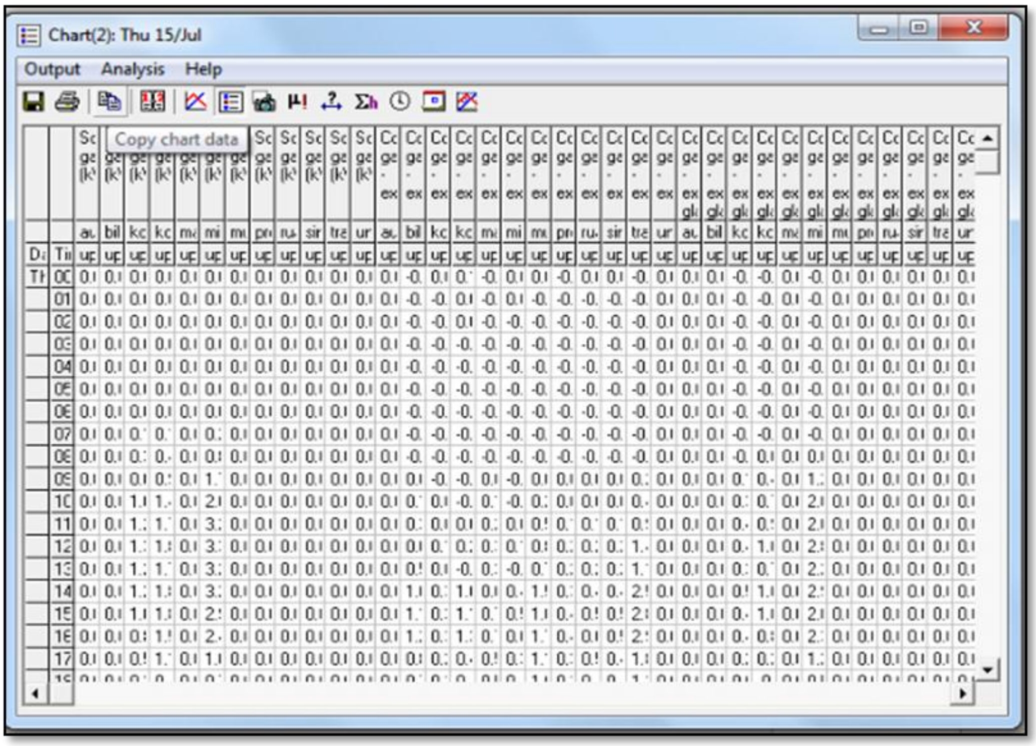

Figure 25: RTTV/OTTV Result from VE

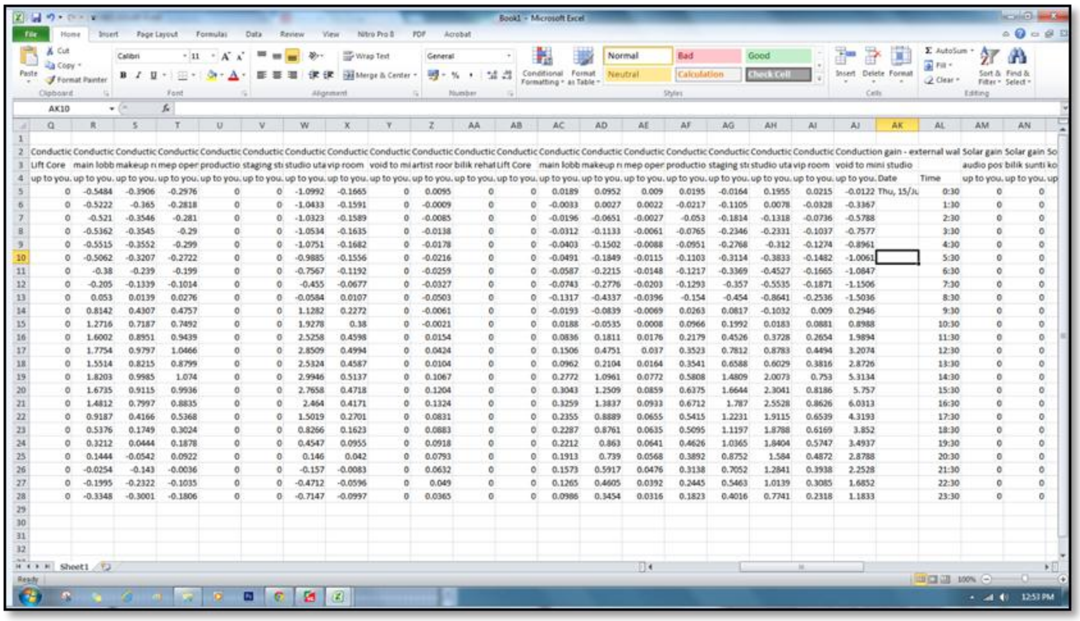

Figure 26: Copying RTTV&OTTV data to excel sheet

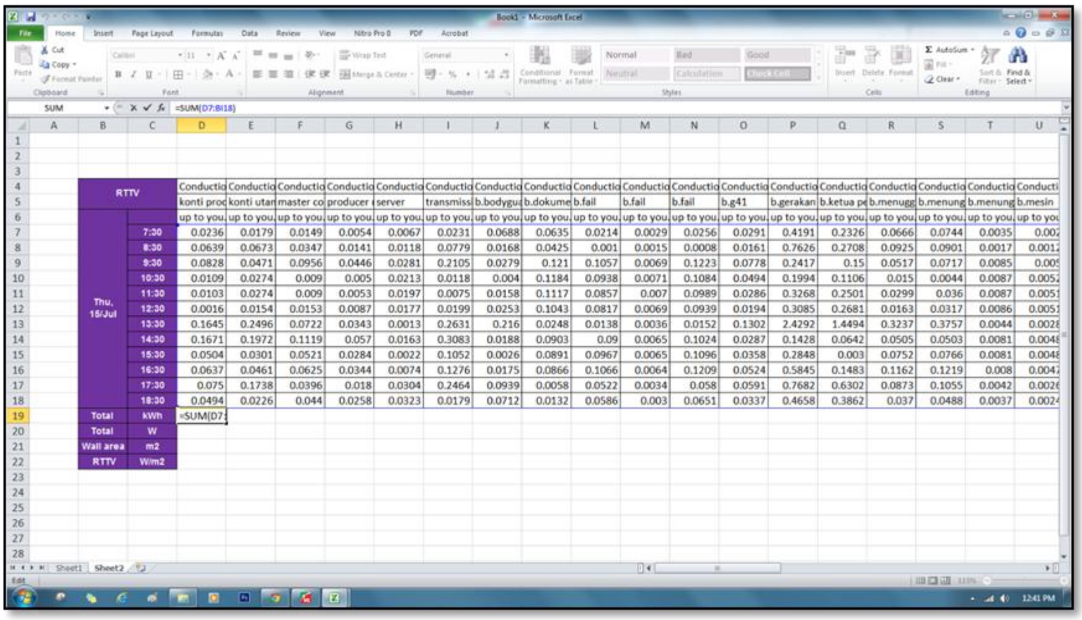

Figure 27: Edit all the table and calculate overall RTTV value

4.2.1.4 OTTV and RTTV Results Overview

The following table summarizes the results from the OTTV and RTTV calculations:

Overall Thermal Transfer Value (OTTV) W/m^2	Roof Thermal Transfer Value (RTTV) W/m^2
49.74	4.47

Table 5: Overall OTTV and RTTV Results

Based on the calculation, the overall OTTV for our model is 49.78 W/m^2 and RTTV is 0.60 W/m^2. Detail OTTV of building for every level as shown in the Table below.

No.	Level	OTTV (W/m2)≤ 50 W/m2
1	Level 1	32.66
2	Level 2	42.29
3	Level 3	46.38
4	Level 4	48.30
5	Level 5	46.13
6	Level 6	48.37
7	Level 7	51.50
8	Level 8	64.24
9	Level 9	67.82
Overall OTTV		49.74
RTTV (W/m2) ≤ 25 W/m2		4.47

Table 6: OTTV Result

4.2.2 BEI Derivation

The Building Energy Intensity (BEI) assessment is analysed using IES VE Dynamic Apache Loads Calculation and is incorporated into the manual BEI calculation of all connected loads in the building. The details of all assumptions and assessment result are explained in the next section. Figure below shows the process flow involved in the simulation to derive the BEI for the development.

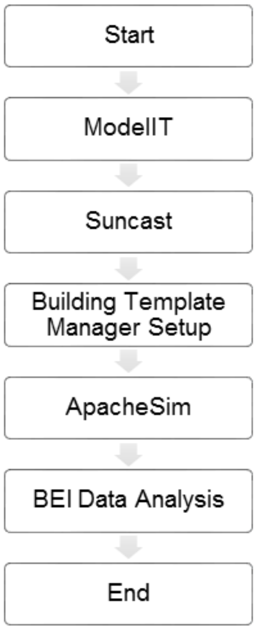

Figure 28: Flow chart for BEI simulation

The Building Energy Intensity (BEI) formula is appended hereunder and it has an allowance for floor vacancy to be excluded should any of the Leased Units not be occupied at CVA stage.

Below is the formula for the BEI calculation:

$$BEI = \left[\frac{TBEC - CPEC - DCEC}{GFA_{(without\ carpark)} - DCA - GLA.FVR}\right] \cdot \left[\frac{52}{WOH}\right]$$

Where;

TBEC : Total Building Energy Consumption (kWh/year)

CPEC : Carpark Energy Consumption (kWh/year)

DCEC : Data Centre Energy Consumption (kWh/year)

GFA *(excluding carpark)* : Gross Floor Area exclusive of car park area (m2)

DCA : Data Centre Area (m2)

GLA : Gross Lettable Area (m2)

FVR: Weighted Floor Vacancy Rate of GLA (%)

52 : Typical weekly operating hours of office buildings in KL/Malaysia (hrs/wk)

WOH : Weighted Weekly Operating Hours of GLA exclusive of DCA (hrs/wk)

4.2.2.1 Weather Data

IES-VE calculates OTTV of the building envelope using real time calculation incorporating local weather data and construction materials of the building. For the record, this simulation will be based on Kuala Lumpur local weather data taken from ASHRAE design weather database. The design weather data is used to determine peak loads, and the simulation weather data is used for the full year simulation.

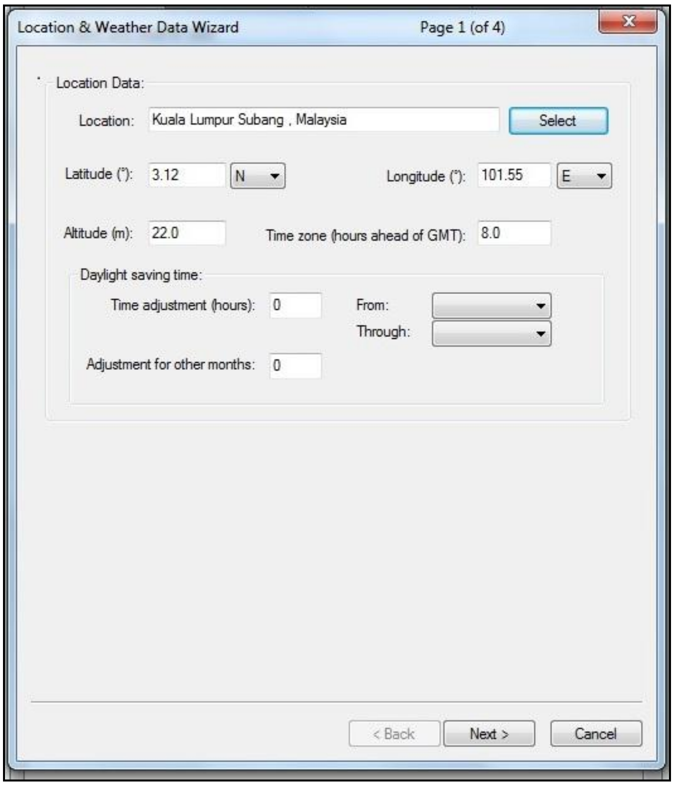

Figure 29: Setting up Location and weather in IES

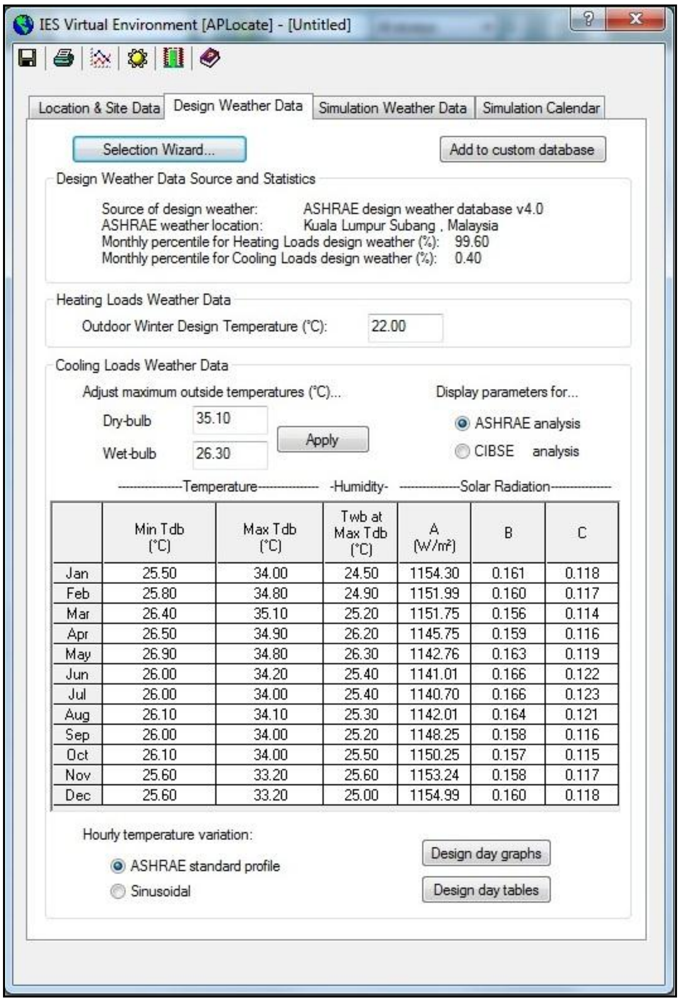

Figure 30: Checking the weather file information

4.2.2.2 Building Template Manager Setup

Time Profile

In this assessment, the building is considered to operate 10.4 hour, 20 days per month and 12 month operation a year. However, the diversity factors are included in the assessment considering the occupancy rate in each spaces of the building.

Air Conditioning Input Parameter

The internal condition of the building is listed in Table 8.0 below. The cooling temperature set point for the whole building 24^{0}C while the humidity is controlled to be lower than 70%.

Temperature Set point	24^{0}C
Humidity Set point	70%

Table 7: Air Conditioning Input Parameter

Mechanical and Electrical Input Parameter

Table below shows the total maximum demand for each mechanical and electrical.

Items	Maximum Demand (kW)
Air Handling Unit	469.8
Lighting	417.51
Plug Load	202.71
Pump	252.84
Fans	219.42
Lift	234.97
Landscape Lighting	0.99

Table 8: Input for IES VE Apache Loads Calculation based on M&E design

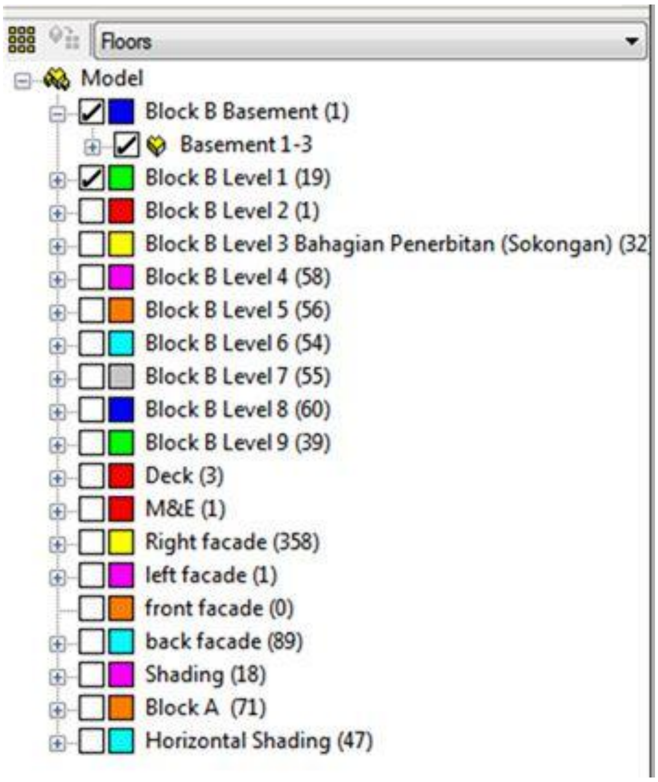

Figure 31: Building detail room and floor layer

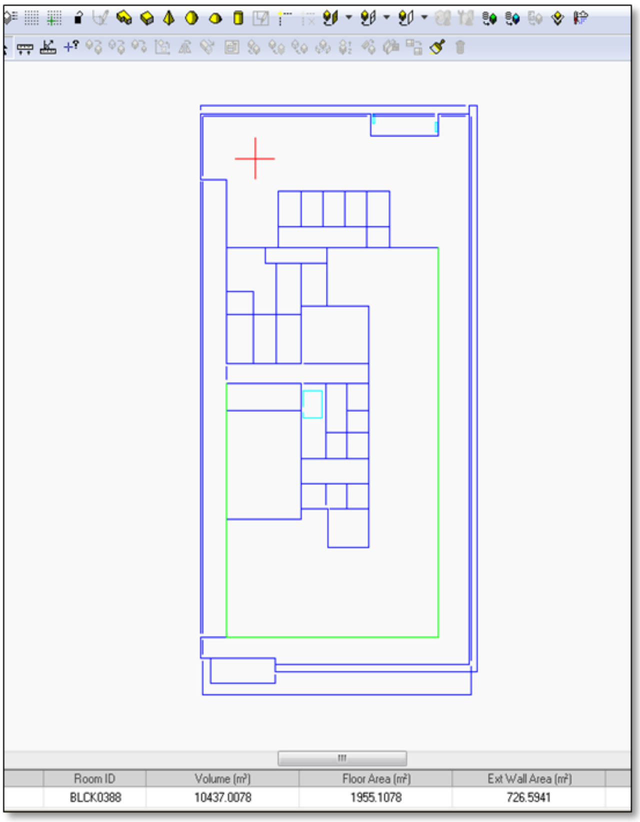

Figure 32: Selected floor level drawing

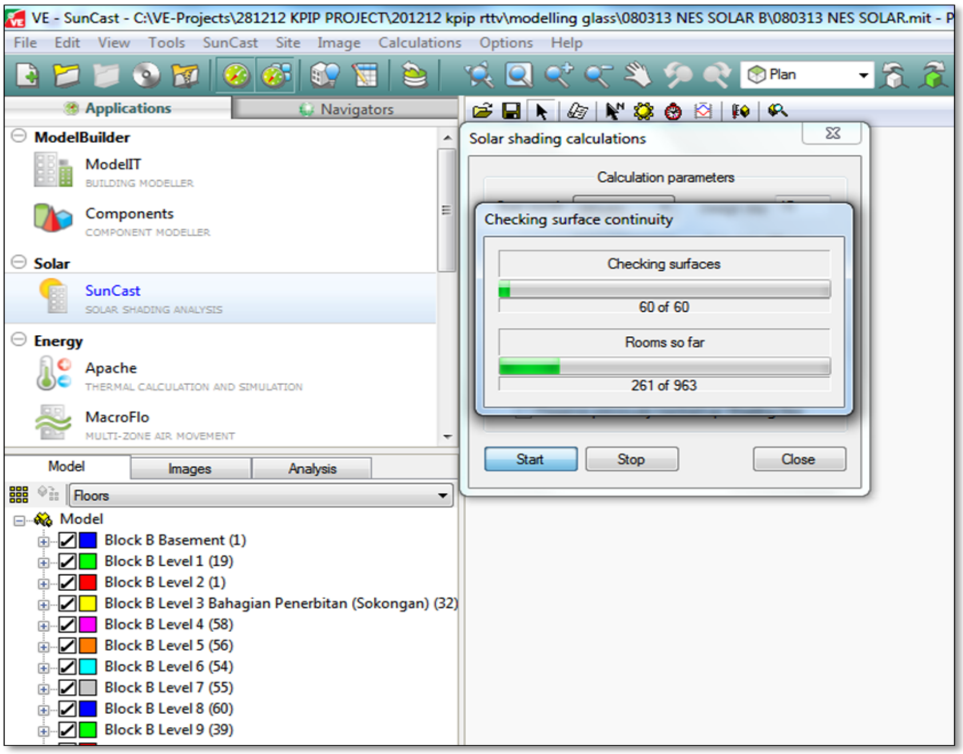

Figure 33: SunCast Analysis

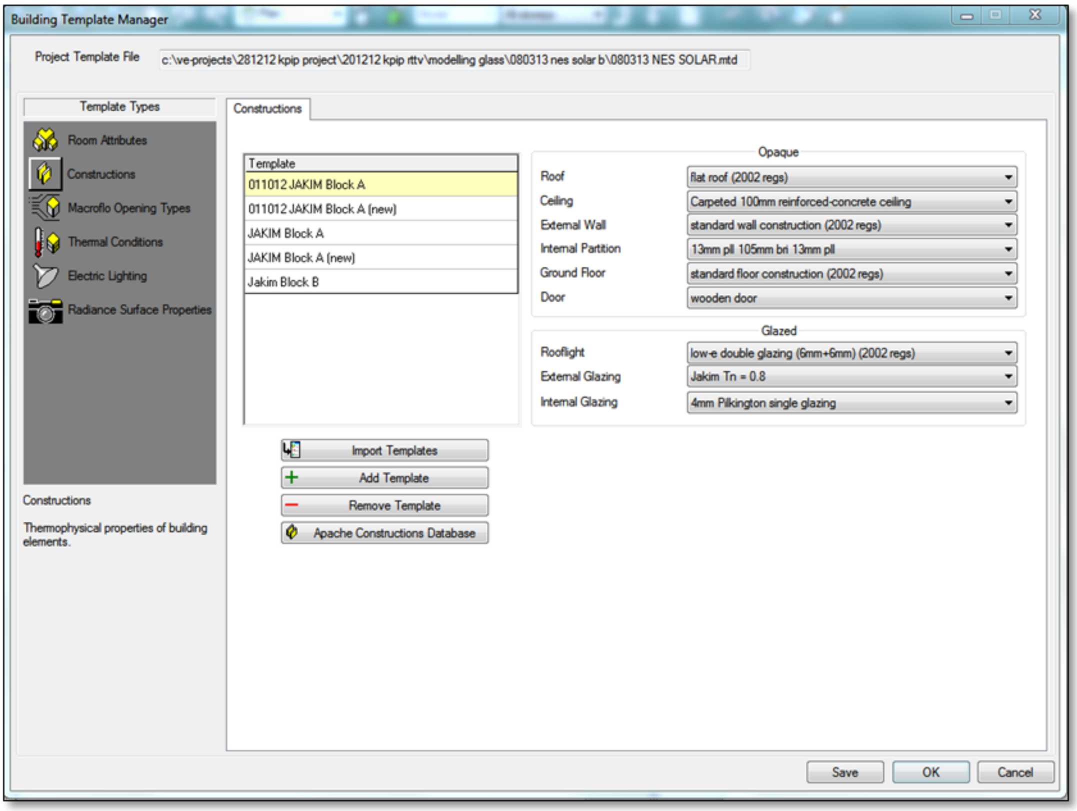

Figure 34: Building Template Manager

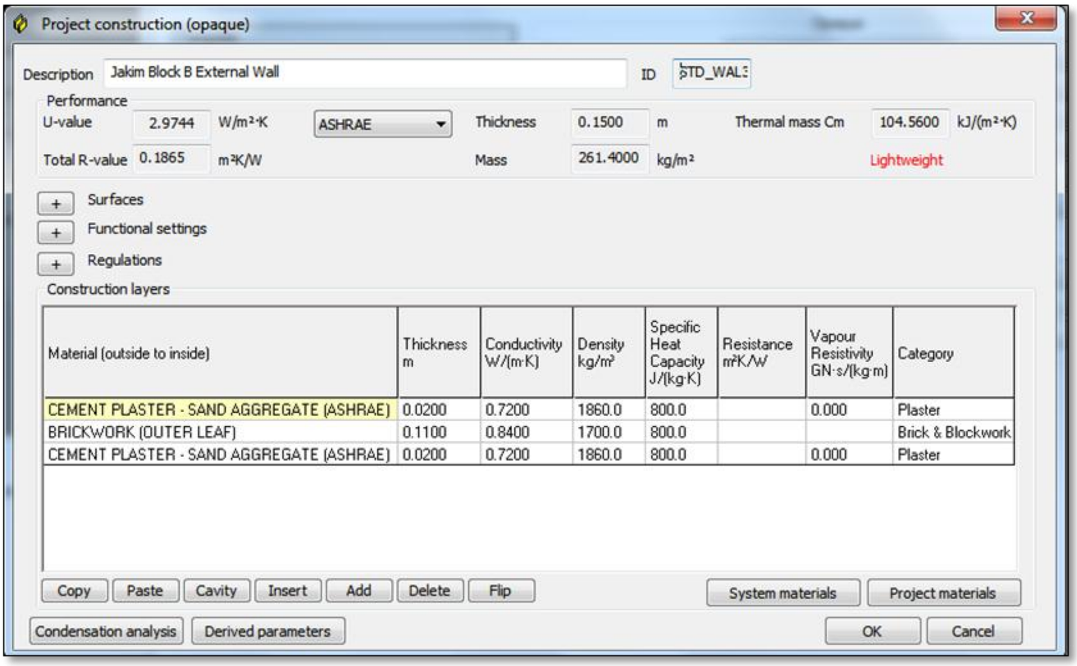

Figure 35: Inputting Building information into the Project construction

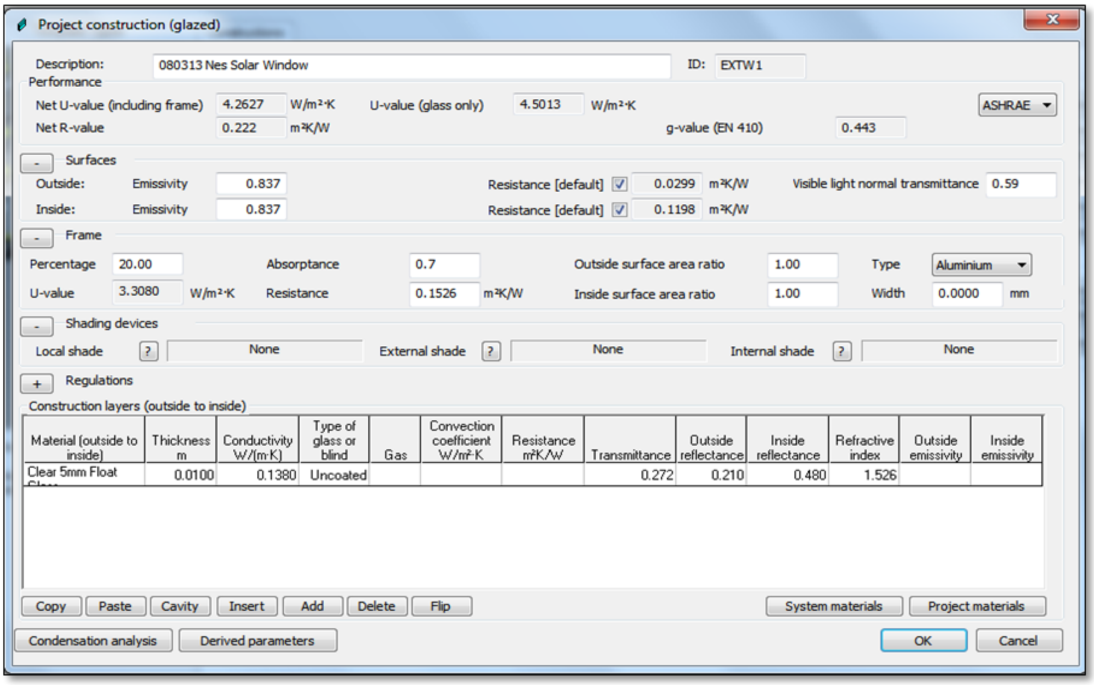

Figure 36: Inputting Building information into the Project construction

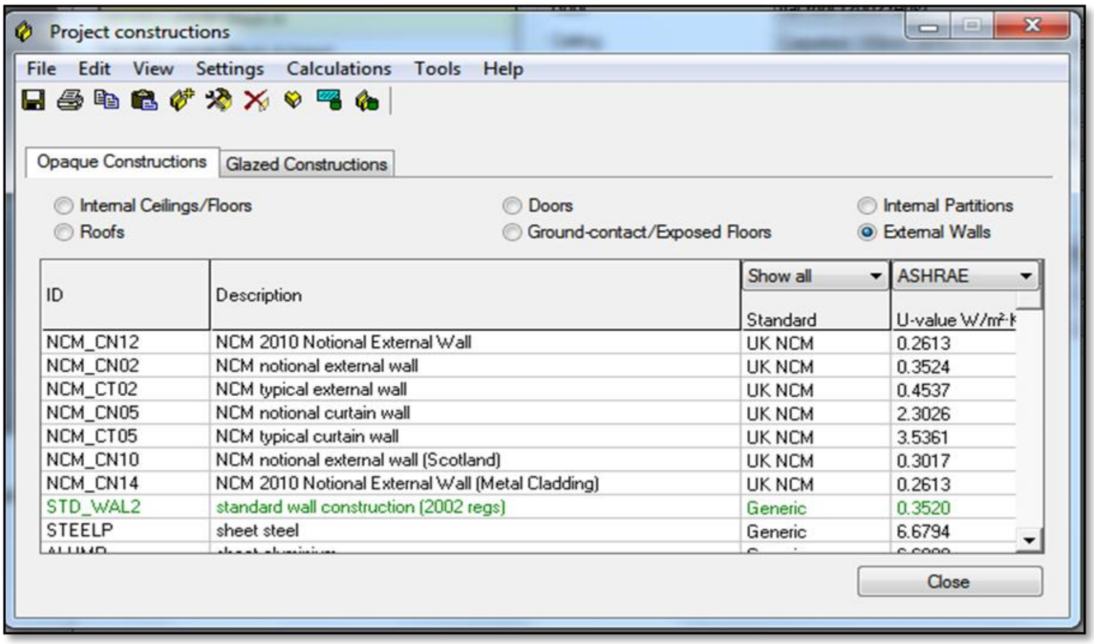

Figure 37: Inputting Glazing information into the project construction

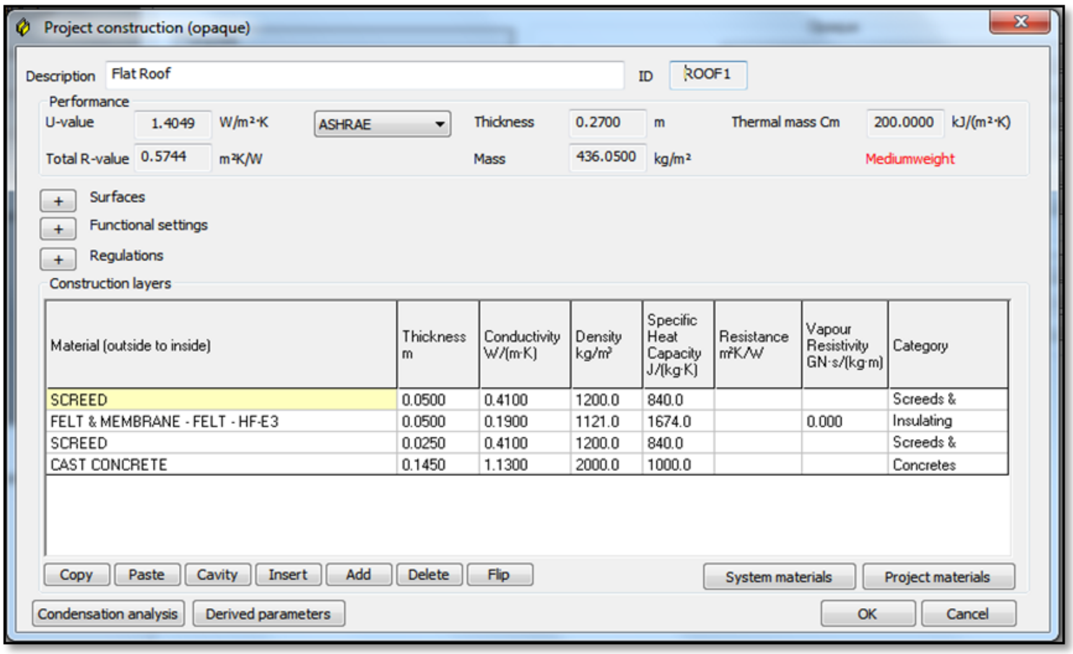

Figure 38: Adjusting Opaque data in project construction setting

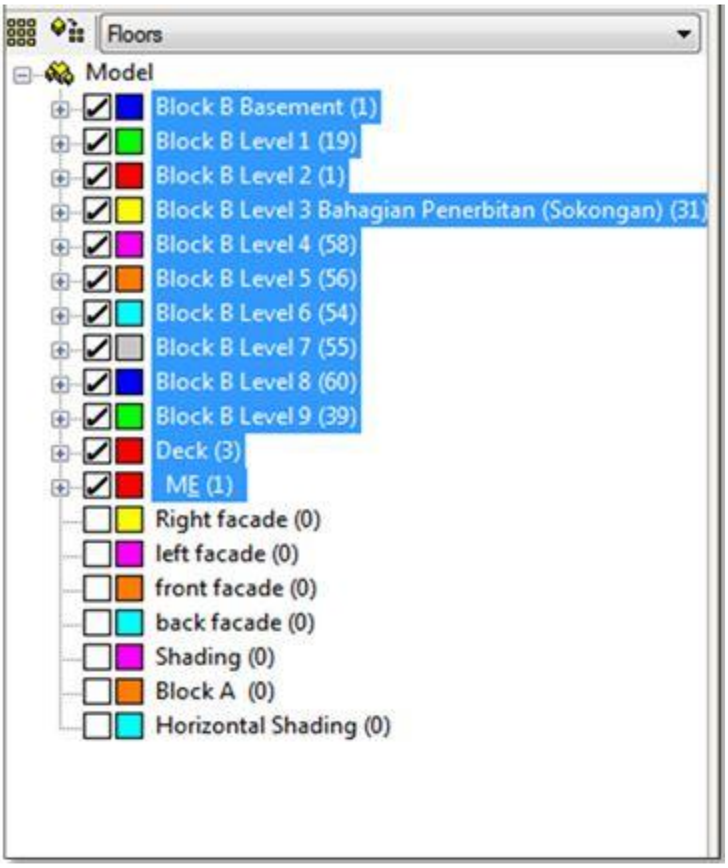

Figure 39: Selecting all occupied layer in the building for analysis

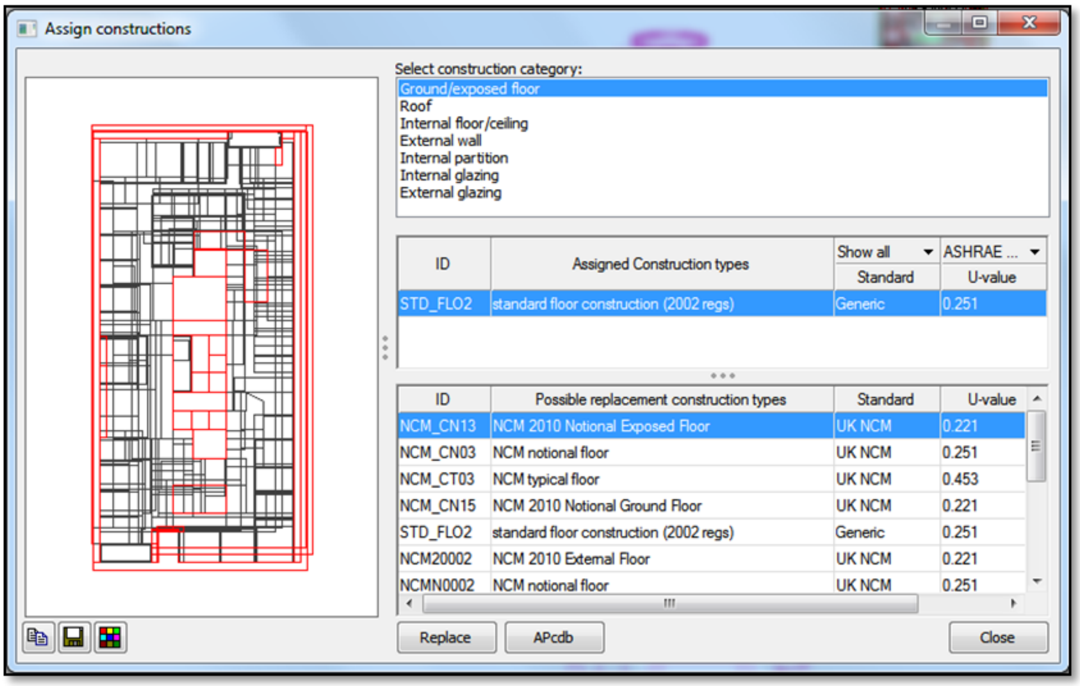

Figure 40: Checking the glazing position of the building

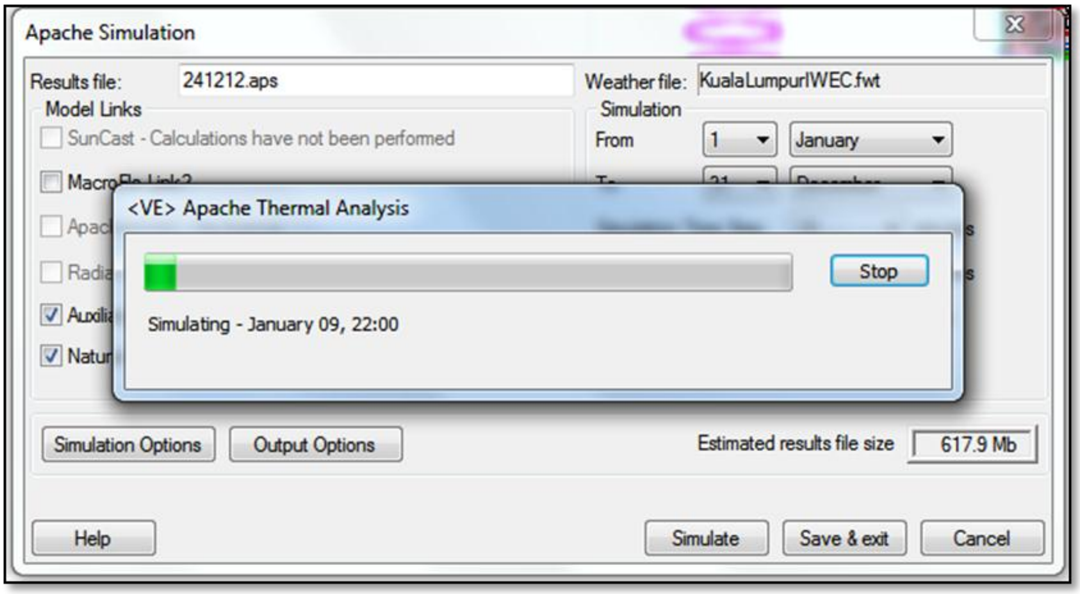

Figure 41: Apache simulation

4.2.2.3 BEI Results and Analysis

The overall value of energy consumption in the model is analysed using IES VE Dynamic Apache Loads Calculation and is incorporated into the manual BEI calculation. This manual calculation is includes all of the energy use in building by specifying the electrical appliance used by the building involved the office area and general area.

The calculated total BEI of the building is 104.68 kWh per m^2 per year involved all the energy consumption from AHU, lighting, pump, plug load, lift, fans and escalators. The manual calculation is using the formula as below:

$$Mannual\ BEI\ Calculation = \frac{[Max\ Demand * Working\ Time_{(10.4\ hours*20\ days*12\ months)}]}{Net\ lettable\ Area}$$

Items	BEI kWh/year	BEI KWh/m2/year
Manual Calculation		
Fans	461,279.50	14.08
Air Handling Unit	426,816.00	13.03
Pumps	382,247.79	11.67
Lifts	463,334.40	14.14
Landscape Lighting	299,520.00	9.14
IES VE Apache Dynamic Simulation		
Chiller Energy	101,455.40	3.10
Chiller Pump	635,641.60	19.40
Heat Rejection System	352,844.11	10.77
Lighting	305,107.60	9.31
Small Power	1,046.00	0.03
Total	3,429,292.40	104.68

Table 9: Summary of Annual Energy Consumption

4.3 Daylighting Analysis

4.3.1 Daylight Factor

MS 1525:2007 defines daylight factor as a form of description of the daylight distribution, penetration and intensity, expressed in percentage. It is a ratio of the internal luminance ($E_{internal}$) at a point in a room to the instantaneous luminance ($E_{external}$) outside the building on a horizontal surface, as follows:

$$DF = \frac{E_{internal}}{E_{external}} . 100\%$$

For example, a DF of 2% means that 2 per cent of the available exterior luminance is reaching a given station point inside the building. Daylight factor differs from lumen and lux measurement in that is a relative, rather than absolute measure. When light shines on the surface of a semi-transparent material, some of it will be reflected, some will be absorbed by the material and some will be transmitted through it. For a given material, the proportion of the light following each of these paths is called reflectance, absorption and transmittance. Transmittance is defined as the ratio of transmitted light to the amount of light striking the material's surface. Reflectance and absorption are defined similarly, so that the sum of the three must always add up.

Shading Coefficient. Shading Coefficient (SC) is the ratio of the solar heat gain admitted through a window to that admitted through 3mm clear glass. Depending on the transmittance of the window at different light wavelengths, the SC may not necessarily be an accurate indication of transmittance in the visible spectrum.

4.3.2 Weather Data

Radiance is driven by hourly weather data on temperature, solar radiation, cloud cover, wind speed, and wind direction. The data is in the form of a Test Reference Year (TRY), which contains mean values for each climatic parameter for the whole year.

Malaysia weather file was used for the simulation and a dynamic simulation of daylight was conducted for a whole year.

Materials	Red	Green	Blue	Total
External wall reflectance	0.7	0.7	0.7	0.7
Floor reflectance	0.4	0.4	0.4	0.4
Ceiling reflectance	0.9	0.9	0.9	0.9
External glazing transmittance	0.42	0.42	0.42	0.42

Table 10: Reflectance and Transmittance of Materials Surface

The table above specifies the reflectance and transmittance values applied to the materials surfaces of the building model. These values are assessed from the artist's impression of the architectural drawings as presented during the design stage. This is deemed to be sufficient to estimate the calculated outcome of the Daylight Factors.

4.3.3 Building Envelope Summary

4.3.3.1 External Glazing

Clear PVB is proposed for the external glazing of the building. The specification of the glazing is detailed as follows:

Layer Description	Thickness	Conductivity	Resistance	Transmittance
	m	W(m-K)	m²K/W	
Clear PVB	0.084	0.2060	-	0.42

Table 11: External Glazing property

U-value (glass only)	4.7444	W/m²·K
Net U-value (including frame*)	4.4686	W/m²·K
Outside surface resistance	0.0400	m²K/W
Inside surface resistance	0.1300	m²K/W
g-value (BS EN 410)	0.5818	
g-value (BFRC)	0.4713	
Visible light transmittance	0.5	
Short-wave shading coefficient	0.4828	
Long-wave shading coefficient	0.1745	
Total shading coefficient	0.6573	

Table 12: External Glazing property

4.3.3.2 External Shading

Skyline Obstructions

It has been assumed that the horizon is not substantially higher than a flat plane – hence hills have not been modelled. There is adjacent building currently exist around the development.

Shading Devices

Shading was useful to reduce glare and afternoon low sun. Use adjacent building and tree as shading is a good invest and especially beneficial in comfort to glare. Direct sunlight can be balance to the building needs.

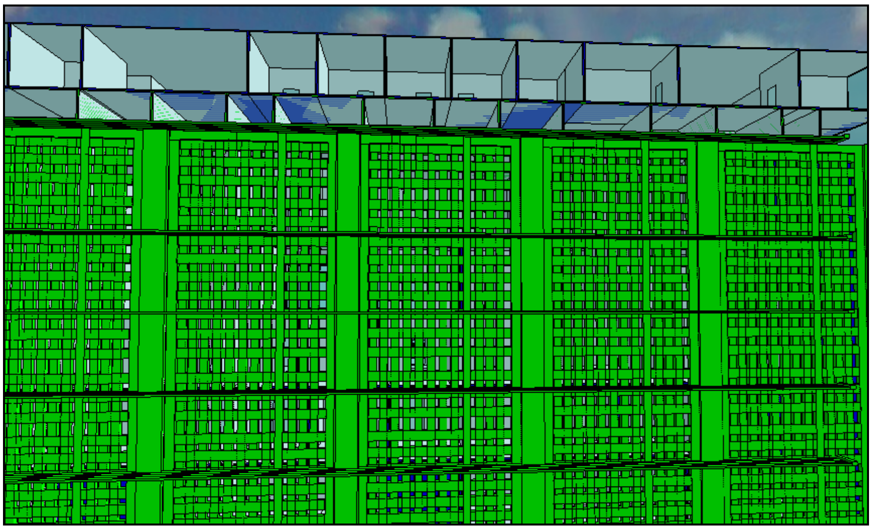

Figure 42: Shading Devices

4.3.3.3 Internal Shading

Roller blinds are proposed for internal windows of the model. It helped to reduce direct sunlight coming into the space and hence reduce high luminance sunlight and glare in the interior space.

4.3.4 Daylighting Results and Analysis

All 9 floor levels are selected for daylight analysis. Each of the analysis is presented with a contour map of the Daylight Factor distribution of the entire floor area.
The suitable colour in contour map and daylight factor to human is from 1-3.5, which under colour light blue to light green.

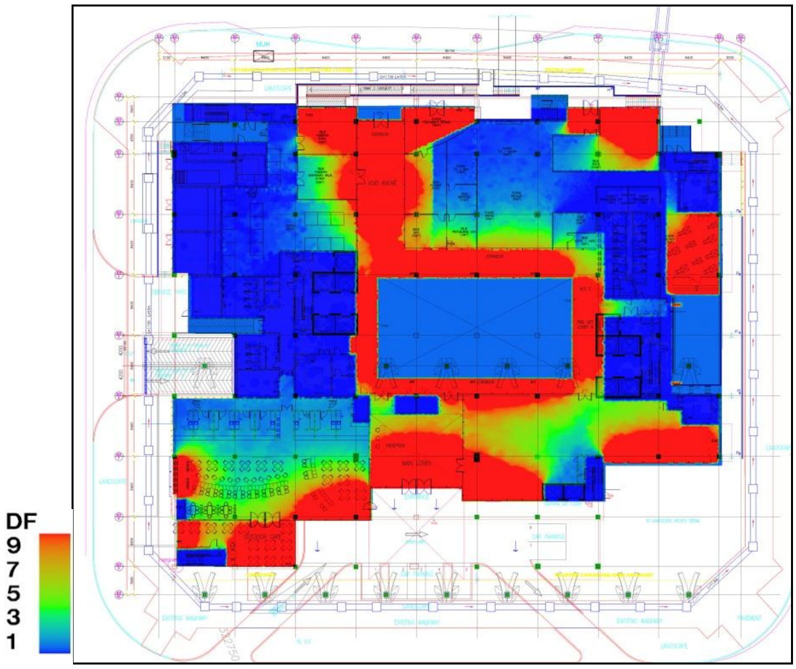

Figure 43: Level 1

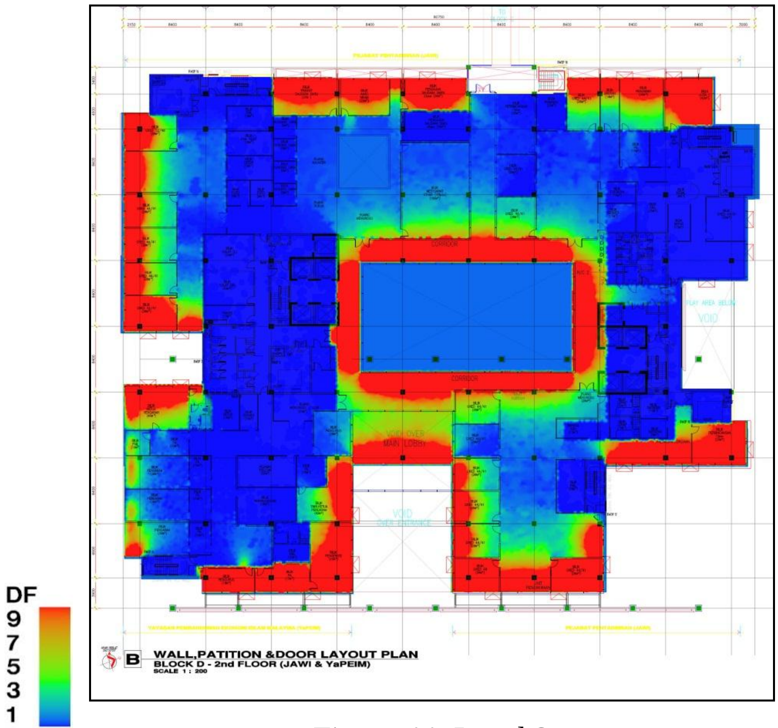

Figure 44: Level 2

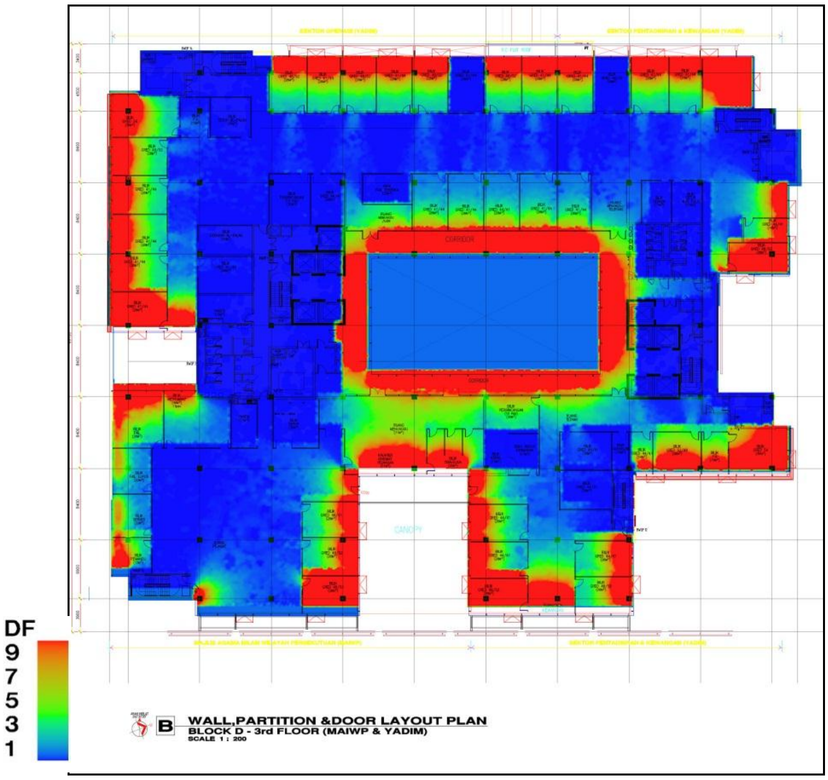

Figure 45: Level 3

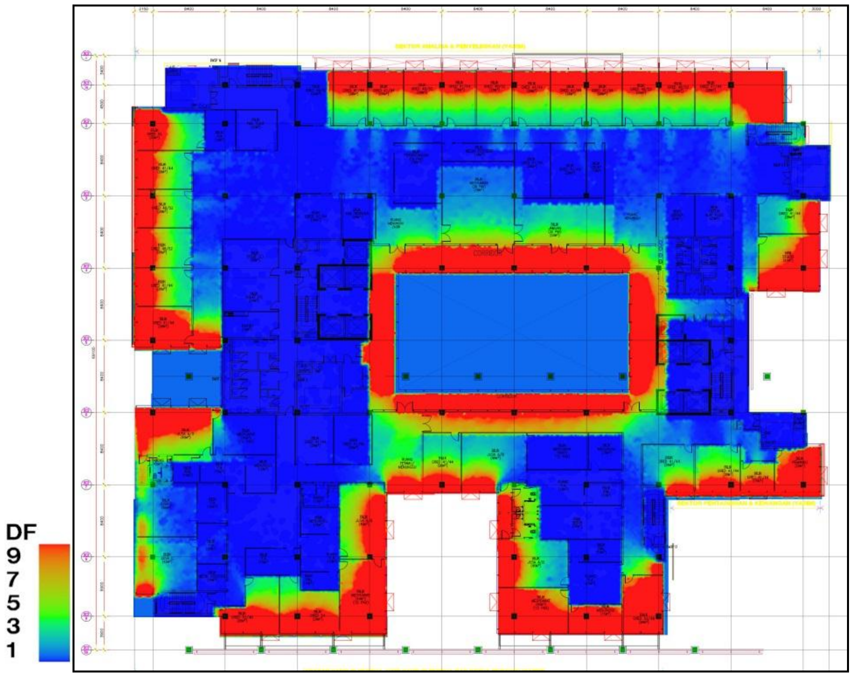

Figure 46: Level 4

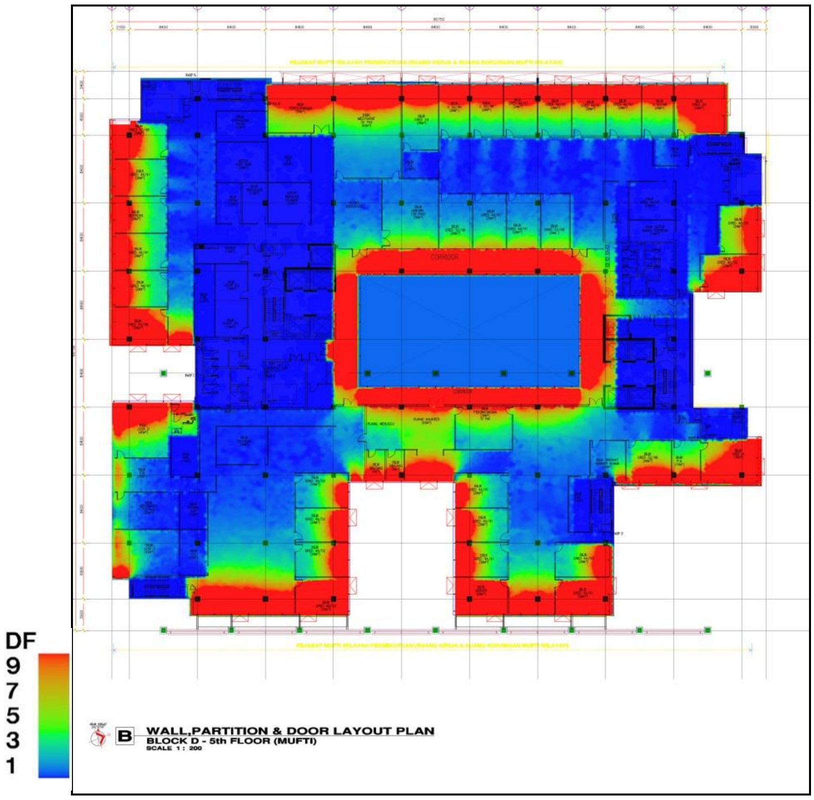

Figure 47: Level 5

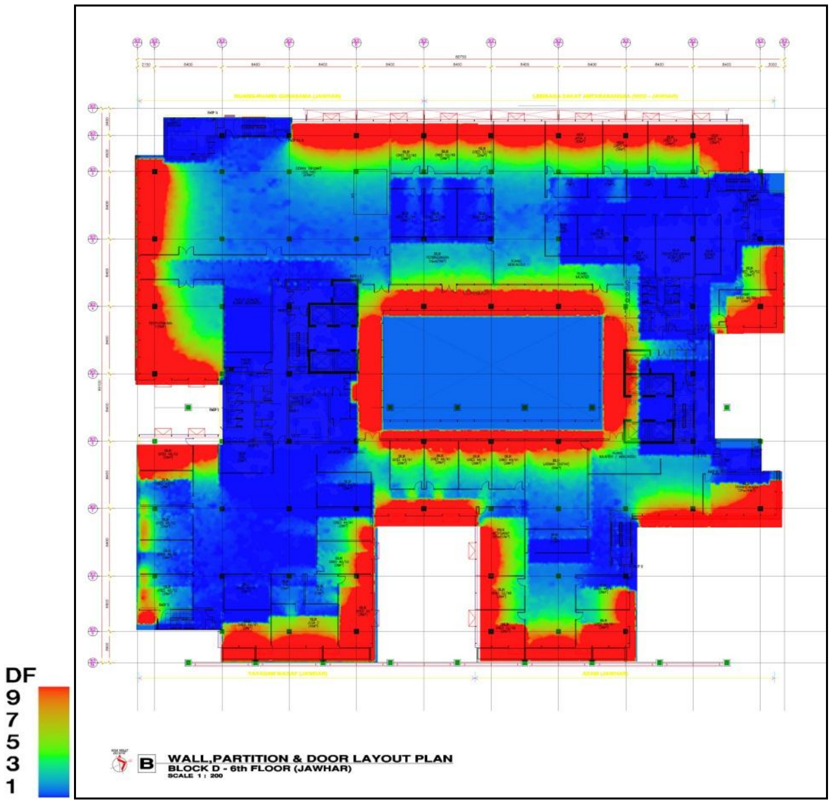

Figure 48: Level 6

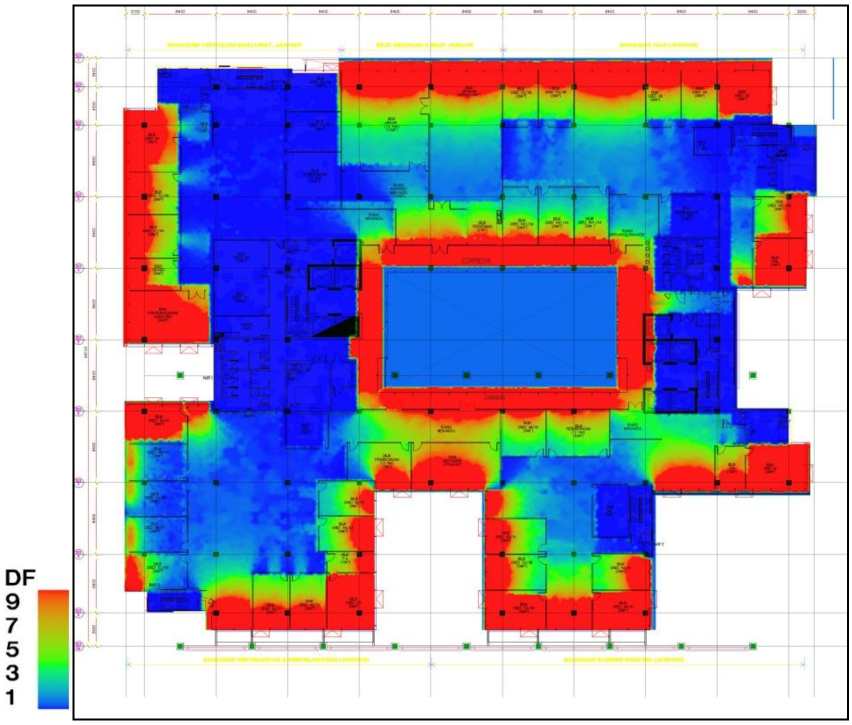

Figure 49: Level 7

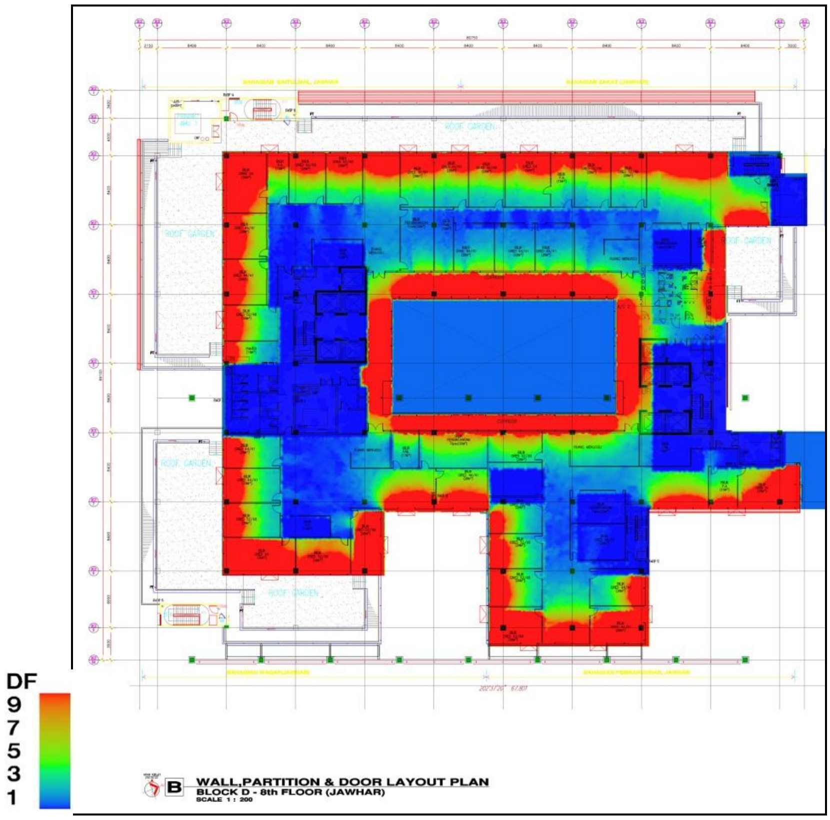

Figure 50: Level 8

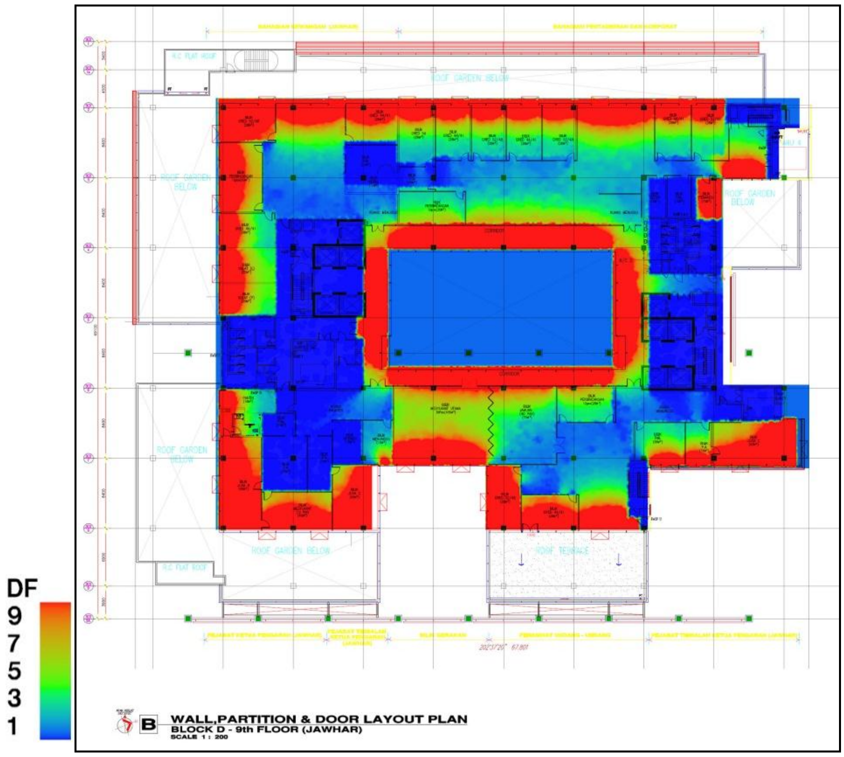

Figure 51: Level 9

4.3.4.1 Daylight Performance Summary

The following table summarizes the daylighting assessment in the model. Daylighting assessment included occupied areas only.

Type	Area DF > 1 (m2)	Floor Area (m2)	% DF >1	Area DF > 3.5 (m2)	% DF > 3.5	1-3.5
Level 1	1885.42	1994.87	95%	646.32	32%	62%
Level 2	1832.33	2833.42	65%	690.12	24%	40%
Level 3	1895.72	3083.12	61%	612.83	20%	42%
Level 4	1958.56	3083.12	64%	698.52	23%	41%
Level 5	1975.06	3083.12	64%	696.55	23%	41%
Level 6	1998.85	3083.12	65%	723.63	23%	41%
Level 7	2214.36	3083.12	72%	842.19	27%	45%
Level 8	1881.8	1969.37	96%	711.90	36%	59%
Level 9	1096.24	1811.67	61%	752.79	42%	19%
% Total			71%		28%	43%

Table 13: Daylighting result

According to the table above, the daylight factor above 1 of the daylight assessment is 43%.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Technology available today can achieve dramatic improvements in building energy efficiency. The challenge in this first phase has been to understand those impediments. With the help from IES-VE, today's building modeling and simulation are one step easier than the previous one. As found in the finding above, the result for energy efficiency and daylighting analysis is quite acceptable. They have met most the green building rating industries such as LEED, Green Star, GBI, etc. Below gives the overall summary of the result obtained from the above finding.

Model's OTTV value	49.74 W/m2
Model's RTTV value	4.47 W/m2
Model's BEI value	104.68 kWh/m2/year
Percentage of area with desirable daylighting factor	43%

Table 14: Overall Project's Result

Advancing energy efficiency measures in buildings is central to Malaysia's national goal of building a low-carbon economy. All stakeholders play essential roles in ensuring energy-efficient construction in their community. The experiences in Hyderabad as well as those nationally and internationally demonstrate that there are many leverage points and strategies for improving building efficiency. Each stakeholder group can take action now through the discrete and achievable steps we’ve identified. The costs of inaction are too high and slow down the improvement of the livelihoods of millions and deter economic growth. Building a green, efficient economy will have tremendous benefits in reducing power cuts, saving money, improving public health, and reducing carbon emissions.

5.2 Recommendation

Energy efficiency improvements are the cheapest way to reduce energy demand and spending, increase energy security, create a new generation of green jobs, and curb rising greenhouse gas emissions. While programs to advance energy-efficient buildings, many challenges remain. Overall, the vast majority of the building sector is far behind in incorporating energy conservation measures into their building designs, with the result that many cities face energy shortages and high electricity bills. Considering the building energy simulation is one of the smartest choice to minimize the cost of building maintenance as well as to produce a low carbon footprint infrastructure.

This report has shown the analysis of energy efficiency and daylight factor based on the real life weather data and actual coordinate of the model’s location. Understanding the OTTV, RTTV, BEI and daylight factor will allow us to see through the expected energy usage of the building through the simulation.

APPENDIX

Appendix A: Building Envelope Specification

External Wall

Layer Description	Thickness	Conductivity	Density	Capacity
	m	W(m-K)	kg/m³	J/(kg·K)
Cement Plaster	0.0200	0.7200	1860.0	800.0
Brickwork (Outer Leaf)	0.1100	0.8400	1700.0	800.0
Cement Plaster	0.0200	0.72000	1860.0	800.0
Inside Surface			0.1198	m²K/W
Outside Surface			0.0299	m²K/W
Total Resistance			0.2169	m²K/W
CIBSE Net U-Value			2.7504	W/m²·K
EN-ISO U-Value			2.8050	W/m²·K
Outside surface absorptance			0.55	
Inside surface absorptance			0.70	
Inside Emissivity			0.9	
Outside Emissivity			0.9	

External Window

Layer Description	Thickness	Conductivity	Resistance	Transmittance
	m	W(m-K)	m²K/W	
5mm ASG Solargray Annealed + 0.38mm Clear PVB + 5mm ASG Clear Annealed Float	0.0104	0.4000	-	0.49
U-value (glass only)	5.1020	W/m²·K		
Net U-value (including frame*)	4.7906	W/m²·K		
Outside surface resistance	0.0400	m²K/W		
Inside surface resistance	0.1300	m²K/W		
g-value (BS EN 410)	0.5817			
g-value (BFRC)	0.4712			
Visible light transmittance	0.49			
Short-wave shading coefficient	0.5000			
Long-wave shading coefficient	0.1570			
Total shading coefficient	0.6570			

Flat Roof

Layer Description	Thickness	Conductivity	Density	Capacity
	m	W(m-K)	kg/m³	J/(kg·K)
Screed	0.0500	0.4100	1200.0	840.0
Felt & Membrane – Felt-HF-E3	0.0500	0.1900	1121.0	1674.0
Screed	0.0250	1.4100	1200.0	840.0
Cast Concrete	0.1450	1.1300	2000.0	1000.0
U-Value			1.3998	W/m²·K
Total R-Value			0.5477	m²·K/W
Construction Thickness			0.2700	m

Roof Garden

Layer Description	Thickness	Conductivity	Density	Capacity
	m	W(m-K)	kg/m³	J/(kg·K)
Gravel – based soil	0.8000	0.5200	2050.0	184.0
Cast Concrete	0.0500	1.1300	2000.0	1000.0
Cavity	1.2000			
Fibreboard	0.0095	0.0600	300.0	1000.0
U-Value			0.4852	W/m²·K
Total R-Value			0.3826	m²·K/W
Construction Thickness			2.0595	m

Appendix B: IES VE Energy Modelling Calculation

Date	Chillers energy (MWh)	Ap Sys aux + DHW/solar pumps energy (MWh)	Ap Sys heat rej fans/pumps energy (MWh)	Lights electricity (MWh)	Equip electricity (MWh)
	091112 10.4h.aps	091112 10.4h.aps	091112 10.4h.aps	091112 10.4h.aps	091112 10.4h.aps
Jan 01-31	54.5648	64.8611	26.1911	40.7011	8.9519
Feb 01-28	53.1521	61.7724	25.513	38.763	8.5257
Mar 01-31	64.4654	71.0383	30.9434	44.5774	9.8045
Apr 01-30	61.1551	67.9497	29.3544	42.6393	9.3782
May 01-31	57.5712	64.8611	27.6341	40.7011	8.9519
Jun 01-30	61.1458	67.9497	29.35	42.6393	9.3782
Jul 01-31	57.4836	67.9497	27.5921	42.6393	9.3782
Aug 01-31	58.3178	67.9497	27.9925	42.6393	9.3782
Sep 01-30	59.0817	67.9497	28.3592	42.6393	9.3782
Oct 01-31	52.7164	64.8611	25.3039	40.7011	8.9519
Nov 01-30	55.9877	67.9497	26.874	42.6393	9.3782
Summed total	635.6416	735.0919	305.1076	461.2795	101.4554
Summed total (kWh)	635,641.60	735,091.90	305,107.60	461,279.50	101,455.40

Overall BEI Calculation

ITEMS	Value
Lighting	461,279.50
Fans	426,816.00
AHU	382,247.79
Pumps	463,334.40
Lifts	299,520.00
Small Power	101,455.40
TOTAL ANNUAL (kWh)	2,134,653.09
GFA (sqm)	32,760.98
BEI (kWh/sqm/year)	65.16
Chiller Energy (District Cooling System)	635,641.60
Chiller Pump	352,844.11
Heat Rejection System (District Cooling System)	305,107.60
Total	1,293,593.31
Landscape Lighting	1,046.00
TOTAL ANNUAL (kWh)	3,429,292.40
BEI (kWh/sqm/year)	104.68

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